JOURNAL
OF THE
AMERICAN WATER WORKS ASSOCIATION

Vol. 38 APRIL 1946 No. 4

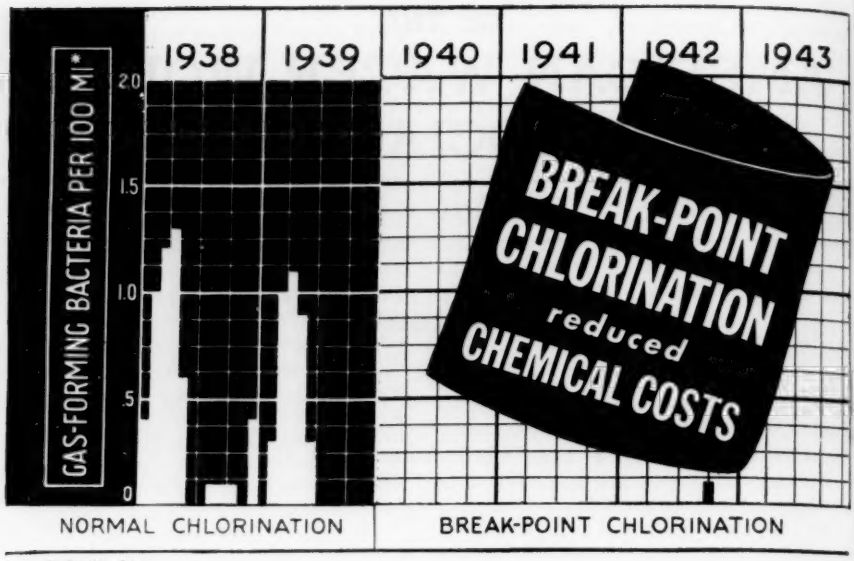
Contents

Utility Employees' Profit-Sharing Plan. By A. P. Kuranz 451
Municipal Water Works Organization in New York State. By E. J. Rowe and C. A. Engelder 455
City Ordinance Against Cross-Connections. By H. H. Caswell 460
Cross-Connections and Back-Siphonage. By Andrew T. Dempster 465
Inspection of Water Works Materials. By H. Arthur Price 472
Carvin's Cove Water Supply Project for Roanoke, Va. By Louis R. Howson 480
Erratum 490
A Wartime Capital Improvement. By W. S. Mahlie and Uel Stephens 491
A Study of Corrosion Control With Sodium Hexametaphosphate. By Peter E. Pallo 499
Water Quality and Pollution Control in Western Pennsylvania. By C. H. Young 511
New Developments in Water Rates. By Charles H. Capen Jr. 525
Chicago's Sale of Water to Outside Municipalities. By William A. Weigel 531
Water Problems in Saskatchewan. By J. G. Schaeffer 537
Tentative Standard Specifications for Cold Water Meters—Current Type—7M.2–T 541
Tentative Standard Specifications for Cold Water Meters—Compound Type—7M.3–T 551
West Palm Beach, Florida—Survival and Retirement Experience With Water Works Facilities 562
Abstracts of Water Works Literature 577
Officers of the Sections viii
Coming Meetings ix
News of the Field 1
Changes in Membership 28
Changes in Address 40

***All correspondence relating to the publication of papers* should be addressed to**

Harry E. Jordan, Secretary
500 Fifth Avenue, New York 18, N. Y.

$7.00 of a member's dues are applied as subscription to the JOURNAL.
Additional single copies to members—50 cents
Single copies to non-members—75 cents



*Indicated Number

...and cut gas-formers 99.2%

Charted above is half of a double-barreled story of Break-Point Chlorination in action.

First, improved coagulation and longer filter runs resulted in a saving in chemical costs of ten cents per million gallons treated. And second, the *free available chlorine residuals* maintained throughout the system by Break-Point Chlorination reduced gas-formers in the finished water 99.2%.

This case shows what Break-Point Chlorination can accomplish. Call your Wallace & Tiernan Representative today for further details. He'll be glad to show you from actual experience — how it can give *your* community a safer water — often at lower cost.

BACTERIOLOGICAL DATA

	NORMAL CHLOR.	B-P CHLOR.	CHANGE
Total Bact. per ml (avg.)			
Raw	588	399	−32.1%
Filtered	1	1	0
Finished	1	1	0
I.N. (Indicated Number) Gas-Forming Organisms per 100 ml			
Raw	70.00	63.07	− 7.0%
Filtered	.89	.02	−97.7%
Finished	.38	.003	−99.2%

"The Only Safe Water is a Sterilized Water"

WALLACE & TIERNAN COMPANY, INC.

MANUFACTURERS OF CHLORINE AND AMMONIA CONTROL APPARATUS

NEWARK 1, NEW JERSEY • REPRESENTED IN PRINCIPAL CITIES

SA-196

JOURNAL
OF THE
AMERICAN WATER WORKS ASSOCIATION

COPYRIGHT, 1946, BY THE AMERICAN WATER WORKS ASSOCIATION, INC.
Reproduction of the contents, either as a whole or in part, is forbidden, unless specific permission has been obtained from the Editor of this JOURNAL. The Association is not responsible, as a body, for the facts and opinions advanced in any of the papers or discussions published in its proceedings.

Vol. 38 April 1946 No. 4

Utility Employees' Profit-Sharing Plan

By A. P. Kuranz
Mgr., Water Utility, Waukesha, Wis.

A contribution to the Journal

THE idea of employees sharing in the profits of a manufacturing plant or any private business is not new; it has been established with varying degrees of success, depending upon many factors. The plan adopted by Waukesha, which provides that employees share in the profits of a municipally owned utility or service, however, *is* new. To our knowledge, there is no other plan like this in effect anywhere in the country.

In developing this plan, there were many objections encountered which might be considered deterrents. Particularly outstanding was the argument that municipally owned utilities are, after all, owned by the community-at-large, and therefore any division of profits would in a sense deprive the owners of either a lower water rate or higher return to the city's general fund. The state of Wisconsin is fortunate in the operation of its publicly owned utilities in that the regulatory features and the rate making device are under the control of the Public Service Commission of Wisconsin, one of whose chief duties it is to see that the customer gets the best possible service at the least possible cost. Because the Public Service Commission is in that position, public utilities can operate more or less on what might be called the private enterprise basis. Section 66.06 of the Wisconsin Statutes is quite clear with reference to the establishment of governing bodies operating municipally owned utilities, particularly Sec. 10, "Management," and Sec. 11, "Charges," which read in part as follows:

Sec. 10.—Management. (a) In cities owning a public utility, the council shall, and in towns and villages owning a public utility the board may, provide for a nonpartisan management thereof, and create for each or all such utilities, a board of three or five or seven commissioners, to take entire charge and management of

such utility, to appoint a manager and fix his compensation and to supervise the operation of the utility under the general control and supervision of the board or council.

(b) The commissioners shall be elected by the board or council for a term, beginning on the first day of October, of as many years as there are commissioners, except that the terms of the commissioners first elected shall expire successively one each year on each succeeding first day of October.

(c) The commissioners shall choose from among their number a president and a secretary. They may command the services of the city engineer and may employ and fix the compensation of such subordinates as shall be necessary. They may make rules for their own proceedings and for the government of their department. They shall keep books of account, in the manner and form prescribed by the public service commission, which shall be open to the public.

Sec. 11.—Charges. (c) The income of a public utility owned by a municipality shall first be used to meet operation, maintenance, depreciation, interest and sinking fund requirements, local and school tax equivalents, additions and improvements, and other necessary disbursements or indebtedness. Income in excess of these requirements may be used to purchase and hold interest bearing bonds, issued for the acquisition of the utility, or bonds issued by the United States or any municipal corporation of this state, or insurance upon the life of an officer or manager of such utility, or may be paid into the general fund.

It will be noticed from these sections of the statute, that first of all, municipally owned utilities are to be under a nonpartisan management and that they have the power to fix wages and salaries of the manager and employees. Section 11 (c) clearly stipulates what shall be done with the income of a municipally owned utility. It follows very readily that if the utility commission were out of line in establishing wages and salaries it would be reflected in the operation of the utility and, consequently, the Public Service Commission would be in a position to raise the question. It also seems reasonable that a profit-sharing plan is entirely proper and the only objection to it might be that it would upset the rate structure and again, the Public Service Commission would be interested in this phase of it.

In considering such a plan, therefore, it was felt that if the arrangements did not in any way affect the final rate structure there could be little objection from any source. This was reasoned to be particularly true in the case of the water utility in Waukesha. Since the commission had established its financial program on the law as propounded in Sec. 11, in that proper provisions were made for local and school taxes, which are assessed against the utility on the basis of capital investment less depreciation, the utility is on the same basis as that of other manufacturing plants, so that the taxes the utility pays the city are on a basis exactly the same as if the utility were privately owned. Since the city, in the early days of the acquisition of the water utility, had invested funds through bond issue, it seemed reasonable that a dividend should be paid on this investment. This, too, is part of the financial setup in the case of the Waukesha Water Utility. In addition to this, an agreed upon sum, which varies from year to year, is paid to apply on the city's equity in the plant.

Since the Public Service Commission of Wisconsin has taken the stand supported by Statute 66.06 (11c), that a utility, even though municipally owned, is entitled to a fair rate on its

investment, and if the utility rates are such that a profit is made, surely those who are in immediate charge of operating the utility have had much to do with making this profit possible. There, then, follows the line of reasoning that the employees are directly responsible for making this profit and no valid reason can be presented against their sharing in the fruits of their labor.

With that idea developed to its logical conclusion, it seemed feasible, just and morally correct that the employees should share in this profit. The next step was to determine the basis upon which such profits should be shared, and the plan of using the employees' salaries and wages was the beginning point. The determination of the total amount was carefully studied and arrived at, on a very arbitrary basis, and it can be argued that there is no justifiable reason for doing it as it is done. Since the idea was so new, however, and since there was no pattern to follow, it was decided to make a bold move and the following motion was developed and put into effect covering the earnings for the years 1944 and 1945:

Waukesha Water Utility's Employees Profit-Sharing Plan

THAT, the employees shall share in the net income of the Waukesha Water Utility as determined by the auditors engaged by the Water Utility Commission each year.

THAT, the net income will be the amount remaining after retirement expenses, local taxes and dividends on the city equity have been deducted.

THAT, the employees share on the basis of 4 per cent of this net total, but that no employee's share shall exceed $200 per year.

THAT, each employee who has been with the Waukesha Water Utility for a period of six months during the year in which the plan is effective, share on the basis of his total wages and salary, including the Salary Savings Plan now in effect for most of the employees of the Waukesha Water Utility.

THAT, said profit-sharing payment shall be made after the auditors engaged by the Water Utility Commission have made their report.

THAT, the plan shall be considered as part of the wages and salaries paid to each employee.

It will be noted in the third paragraph that the figure 4 per cent of the net total was used, which is the figure referred to as "arbitrary" in a previous paragraph. One other feature of importance was that a limit of $200 per year was established because, since most municipally-owned utilities have one or two, or at least only a few, top-paid employees, there might be a feeling of inequality among the employees themselves and certainly from the employee's angle a much better feeling would be created if the top-salaried men would be limited in their share. The total amount set aside under the plan, however, did not vary, so the amount that the manager and other top paid employees *did not* receive according to the sharing set-up was redistributed among the lower paid employees, so that in Waukesha's case the effect of the profit-sharing plan was a salary increase ranging from 3.6 per cent for the high-paid employees to about 8 per cent for the low-paid employees. The payment of the profit-sharing is made after the State Tax Commission auditors have completed their audit and after the utility's reports have been made to the Public Service Commission. These checks are issued within a few months after the close of the year in which the plan is effective.

Up to this point, all of the activity originated with the local water utility commission and proper action was taken to put the plan into effect locally. After this was done and the provisions of the employees' profit-sharing plan carried out on the basis of 1944 earnings, the plan was discussed with the Public Service Commission and after several exchanges of correspondence and visits to the Public Service Commission, attention was called by the Commission to Sec. 196.11 of the Wisconsin Statutes, which is as follows:

Sec. 196.11.—Profit Sharing and Sliding Scales. (1) A public utility may enter into any reasonable arrangement with the customers or consumers or with its employees, for the division or distribution of its surplus profits, or providing for a sliding scale of charges or other financial device that may be practicable and advantageous to the parties interested. No such arrangement or device shall be lawful until it shall be found by the commission to be reasonable and just and consistent with the purposes of this chapter. Such arrangements shall be under the supervision and regulation of the commission.

It must be confessed that the statute apparently *did* provide the local water utility commission with legal authority to put the plan into effect, so the Public Service Commission thought that a public hearing should be held on the plan and set the date of the hearing for Nov. 20, 1945. On January 15, 1946 the utility received the following from the Public Service Commission of Wisconsin:

PUBLIC SERVICE COMMISSION OF WISCONSIN

The Commission Finds and Determines: That the employee profit-sharing plan of the Waukesha Water Utility, as discussed above, is reasonable and just and consistent with the purposes of Chapter 196 of the Statutes.

Dated at Madison, Wisconsin, this 15th day of January, 1946.

This finding and determination, of course, provided the legal authority to make the plan legally effective and it gave much support to the local water commission. If the net result of the plan as originally intended works out to any degree of success, the local water commission feels very strongly that it may become a permanent plan; at least the water utility commission feels that the plan should create not only better public relations but also better employee-manager relationships.

Municipal Water Works Organization in New York State

By E. J. Rowe and C. A. Engelder

Supt., Water & Light Dept., Wellsville, N.Y.

Accountant, Water & Light Dept., and Secy., Tri-County Water Works Group, Wellsville, N.Y.

Prepared for the A.W.W.A. Committee on Municipal Water Works Organization

BECAUSE municipal water works organization in New York State is so dependent upon the laws of the state, an examination of the laws themselves tells much of the story of the methods of management.

The type of organization varies with the type of political subdivision operating it. New York has four classifications of political subdivisions, namely (1) cities, (2) villages, (3) towns and (4) counties. The cities generally operate under special charters. Their provisions cover such a wide range of conditions that they are too extensive to merit more than passing reference here. Generally the charters stipulate the method of management of all functions of the municipal corporation. Villages can be divided into two general groups, namely, those incorporated and controlled by a mayor and board of trustees, with or without a village manager, and unincorporated villages. There are provisions in the law for the establishment of water districts. These may be formed in any political subdivision of the state except a city. It is customary for towns and unincorporated villages to establish water districts to serve their inhabitants. Such districts may embrace all or parts of more than one village, town or county. There are no town or county operated water systems, as such, in New York.

The formation of political subdivisions is regulated by two general laws: the "general municipal law" and the "village law."

The general municipal law relates to all subdivisions, whether cities, counties, towns or villages. It defines and states their rights, privileges, limitations and liabilities as municipal corporations. This law is confined to such legislation and statutes as relate to more than one division. The establishment of water districts is within the provisions of the law, which also contains the necessary provisions for the operation of a Mutual Aid Plan for water service and interconnections between systems.

The village law contains specific provisions as applied to incorporated villages. It authorizes the creation of separate boards of commissioners to control public utilities, etc. Such boards are appointed by, and subject to removal at the pleasure of, the governing body of the municipality. When authorized by resolution adopted by the governing body and approved by majority vote of property owners, the board of commissioners may acquire, buy or construct a water system. The establishment of rates, rules and regulations, auditing of accounts, purchase

of materials and employment of labor are under the control and supervision of the commission. There is a similar provision elsewhere for the creation of a board of commissioners to operate a water system in a water district.

Financing

Funds for the acquisition or construction of municipal water systems are generally raised by bond issues. Such issues must be authorized by the controlling body of the municipality and be approved by a general referendum of property owners. Bonds issued as above are excluded from the indebtedness limitation of the municipality. The term of all bond issues is controlled by the local finance law. The maximum life permitted for water system bonds is 40 years, except for the allowance of 50 years in New York City. Bonds covering replacements, except meters, are permitted a maximum life of fifteen years. Bonds for meters are fixed at ten years, with their replacements at five years, except where meters constitute a part of the original acquisition or construction, in which case the life is considered the same as that for the system. Funds for extensions and improvements may also be raised from water rents, frontage tax and assessments for fire protection service. Any building and the lot upon which it stands, whether using water service or not, may be assessed for fire protection when situated within 500 ft. of a hydrant.

The law contains a special provision whereby permission is granted municipalities to sell surplus water to corporations, individuals or water districts outside their limits at such rates and under such conditions as the board may fix.

Under the budget system as used by the cities and many of the other subdivisions, all unexpended appropriations, receipts or other revenues revert to the general municipal fund at the end of the fiscal year. In 1939, the law made provisions for the establishment of reserve capital improvement and maintenance funds. These funds can only be accumulated and expended for specific purposes. The interpretation of the law that such annual balances as may accrue be turned over to the governing political body results in the failure to provide ample working capital so necessary for the proper management of the system.

Municipal Control

New York State has a population of approximately 13,842,500, with about 70 per cent living in or near metropolitan areas. Information published by the State Department of Health shows that in 1940 about 12,946,000 persons (93.5 per cent) were served with water from the public water supplies ranging in size from a community of 25 inhabitants served from a spring to New York City, with its gargantuan system of reservoirs and aqueducts. There were 800 such public water supplies serving 1,228 communities. Persons numbering 12,189,000, or 94 per cent of those served by public supplies, received treated water. About 10,250,000 (79.2 per cent) of the people receiving water from public supplies were served by a municipally operated system.

Last fall some 102 questionnaires were mailed to the water operating officials of municipally owned systems in communities of over 5,000 population. Forty-six replies were received, representing twenty-seven cities, eighteen first-class villages and one water dis-

trict. Four cities and one village had the manager form of government.

Combining the information received from a tabulation of these questionnaires with the Department of Health's records gives the basis of the following discussion.

A check made of 694 municipal water systems operating in the state showed that 370 (54 per cent) were village operated, 273 (39 per cent) were water districts and 51 (7 per cent) were city operated systems.

The village systems may be grouped into three classes:

1. Board of Trustees directly operates system; this method is used by 65 per cent of the villages.

2. Board of Commissioners, appointed by a Board of Trustees, operates system; this method is used by 33 per cent of the villages.

3. Department of Public Works, reporting to a Board of Trustees, operates system; this method is used by 2 per cent of the villages.

The operating head of all these types of village systems is almost universally titled "Superintendent."

The water district systems may likewise be grouped into three similar classes:

1. Town Board directly operates system; this method is used by 61 per cent of the districts.

2. Board of Commissioners, appointed by a Town Board, operates system; this method is used by 35 per cent of the districts.

3. Special Board operates a joint district; this method is used by 4 per cent of the districts.

In all but Class 3 the systems are quite small and the operating head is usually a part-time employee without a fixed title. The head of a special water district is usually "Superintendent," but sometimes is called "Manager."

Because of their special charters and other peculiarities of an individual case, city systems cannot be readily grouped into general classifications. They may be operated as part of the Department of Public Works, as a separate department, as a bureau or as a board. Their operating heads are called, among other things, "Superintendent," "Director," "General Manager," "Chief Engineer," "City Engineer," "Engineer," "Commissioners," etc.

State Control

The control of water works organizations by state agencies is fairly complex and varied.

The State Conservation Department controls the use and primary source of all water within the state. Plans for extensions of supply or distribution, new systems, major alterations to existing systems, either for domestic service or fire protection service, all must be approved by the Water Power and Control Division.

The State Department of Health makes rules and regulations for the protection from contamination of all potable water supplies, controls the method of treatment of public water supplies and establishes qualifications of supervisory personnel. The Public Health Council of the State Department has adopted standard qualifications for three grades of water works operators. A certificate issued pursuant to their procedure must be held by the head of all stipulated public supplies. Plans for new subdivisions of lands must show the method of supplying water service, such to be approved by the department prior to recording with county clerks.

The annual financial and operating reports of municipal water systems are incorporated in the general municipal report and filed with the State Department of Audit and Control. Periodic examinations are made of all branches of government by auditors from this department. Control by the Public Service Commission is very limited. Municipal water systems are required to file a copy of their annual report with the commission, the form of such report not being prescribed. Experience indicates that the affairs of all municipal water systems must be completely regulated by resolutions duly adopted and recorded by the governing body. Any expenditure, change or alteration not so authorized may be subject to question by examining personnel.

The Public Works Law provides that all contracts, in excess of $25,000, shall be publicly advertised.

The State Constitution provides that all employees of the state and its political subdivisions shall be within the jurisdiction of the state civil service regulations. There is a wide diversity of classification of employees, especially in the category of supervisory employees who in the state may be exempt, non-competitive or competitive, as the local situation dictates.

The state law provides for an 8-hour working day and prohibits payment for overtime to any employee. Full compliance with this provision is practically impossible and it entails hardship even to pay lip-service to such a regulation. A recent decision handed down by the courts was to the effect that Article 8 of the Public Works Law applied in full force to all civil subdivisions of the state. This article requires the payment of the "prevailing rate of wages" to all employees. The translation of that opinion into actual practice has proven difficult, due to the wide variance of the "prevailing rate" at the local community level. Workmen's compensation insurance is compulsory for all employees. This protection is given through policies issued by standard insurance companies, the State Insurance Fund or by participation in County Mutual Insurance. There are several outstanding examples of effective and economical operation of the county plan. The so-called "self-insurance," which is extended by the county to all subdivisions within its bounds, is found in many of the water works organizations of the state.

Effective in 1939, all public and quasi-public employees were permitted to join the State Retirement System. This system permits retirement for physical disability or upon reaching the ages of 55 or 60 years. Retirement is compulsory at the age of 70 years. Inducements offered by membership in the state retirement plan, together with the application of the principles of civil service, should attract a desirable class of young men into the municipal water works field; that is, career men. Judging from available information, the tenure of employment of supervisory personnel appears to be of sufficient length to insure experienced and competent supervisors. The educational program of the State Department of Health, in co-operation with the mayors' conference, has produced admirable results in training and refreshing employees.

Results of Survey

The questionnaires which were sent out revealed what is considered a highly significant feature of water system management in the state. The 46 com-

pleted forms represented systems (exclusive of New York City) which serve 59.6 per cent of the municipally operated territory in the state on a population basis. The answers, therefore, may be considered as typical and representative of the whole. One series of questions asked if the present form of management was suitable and satisfactory. The answers to these questions are summarized below:

	Yes, %	*No*, %
Villages without separate board	60	40
Villages *with* separate board	100	0
Cities without separate board	50	50
Cities *with* separate board	100	0

These answers, it must be understood, are those of the operating men who are responsible to the community and to their own consciences for a job well done. The authors feel that any other comment on the situation revealed above would be superfluous.

The widespread practice of diverting the earnings of the water system to general municipal use prevails throughout the state. When water systems are operated by a separate board, the revenues from the operation of the system are often assumed to be earmarked for their use and control. In many instances such earmarking is respected. In all the other cases, due to a provision of the law which stipulates that all such revenues are a part of the general fund, the control of this money is not left with the water system. Whether the system is conducted upon a strict budget system or whether water system balances are subject to the jurisdiction of the local political governing body the result is the same. This practice of diversion restricts proper management of the water works organization. It fails to provide proper and necessary reserve funds for future extensions and maintenance work, it fails to provide incentive for efficient and intelligent operation and it is a terrific obstacle to intelligent long-term planning and management. The failure of political governing bodies to appreciate the inherent value to the community of a well-operated and -maintained water supply and distribution system often results in a reduction in value of this asset. It is regrettable that these bodies give preference to the present tax rate rather than ignore adequate compensation for the operating personnel and maintenance of property efficiency. The advantages of long-term planning would be available provided the outmoded laws controlling the operation of municipal utilities were revised to recognize the difference between the proprietary and governmental functions of local governments.

A long-term program of education of the public, particularly students, to demonstrate the community value of water supplies seems desirable. It is the authors' opinion that this program should originate within the local organization, reinforced by activities of national groups and state departments.

City Ordinance Against Cross-Connections

By H. H. Caswell

Mgr., Water Dept., Ann Arbor, Mich.

A contribution to the Journal

THE potential hazards to the public health of the community through the possible existence of cross-connections has long been recognized by the city of Ann Arbor. With this in mind, the city undertook to make a cross-connection survey, with the intention of establishing an ordinance which would protect the public supply from the dangers of contamination due to defective plumbing.

Since its inception, the idea of making a cross-connection survey was actively supported by Professor Russell A. Dodge, a member of the Water Board; Dr. John Wessinger, Director of the local health department; and Alderman Wm. J. Saunders, Chairman of the Ordinance Committee. Public health men from the University of Michigan, the Detroit Health Department and the Michigan State Department of Health lent their enthusiastic co-operation.

The survey was conducted by William Samborski, Special Investigator of the Water Department, who had done similar work for the city of Detroit. Great care was taken to make a record of every existing cross-connection, regardless of its nature and potential hazard. As was expected, cross-connections of every description were found, despite the fact that the city of Ann Arbor has what is considered a very good plumbing code. Some of the typical cases found are listed below:

1. Greenhouse manure water lines.
2. Gut cleaning machine in slaughter house.
3. River water supply lines to shower bath in the gas works.
4. Various plating tanks in plating works.
5. Rinsing tanks in metal treatment process.
6. High-pressure fire line from experimental tank.
7. Various tanks, sinks, experimental setups, sterilizing apparatus, washing, rinsing and treatment processes in laboratories and hospitals.
8. Commercial laundry washing machines.
9. Plumbing fixtures of all kinds and descriptions in homes, apartment houses and hotels.
10. Cross-connections were found even in the latest model of automatic clothes and dish washing machines.

The work of developing the ordinance was carried out in a very orderly manner. A great deal of educational work was done and all those who might have an interest were asked to participate. Many very helpful suggestions were made by local engineers, plumbing concerns and public health officials. No attempt was made to hasten the work merely to prepare something that might serve as an ordinance, but rather

an effort was made to create something of value to the public welfare of the community.

At no time did the public express opposition to the plan. The industrial and commercial establishments were very much interested in the work and were very co-operative in making suggested changes to conform to the terms of the ordinance.

It is hoped that this ordinance, reprinted in full below, may be of value to the water works field and to public health officials of other communities.

ORDINANCE NO. 102

AN ORDINANCE TO REGULATE THE INSTALLATION OF PIPES, TANKS, FIXTURES AND OTHER DEVICES IN WHICH CITY WATER IS USED; TO PROTECT THE CITY WATER SUPPLY OF THE CITY OF ANN ARBOR, AND TO PROVIDE A PENALTY FOR THE VIOLATION THEREOF.

The Common Council of the City of Ann Arbor ordain:

Sec. 1.—That the following words and phrases when used in this ordinance shall, for the purpose of this ordinance, have the meaning respectively ascribed to them as herein set forth.

Sec. 2.—*Definitions.*

(a) *Cross-Connection.* A cross-connection or interconnection is any physical connection between the city water supply system and any waste pipe, soil pipe, sewer, drain or any private or secondary water supply system. Furthermore, it is any city water supply outlet which is submerged or can be submerged in waste water and/or any other source of contamination.

(b) *Secondary or Dual Water Supply.* Secondary or dual water supply is any water supply in a building or premises maintained in addition to the city water supply. A secondary water supply source shall include any source other than the city water supply system, such as surface water from rivers, lakes, ponds, lagoons, reservoirs and cisterns, and ground water from both deep and shallow wells; also any supply of city water which has been stored, held or reserved after having left the city water supply outlet, or any city water which has in any way been treated, processed or has been subjected or exposed to contamination of either bacterial or chemical nature.

(c) *Back-Siphonage.* Back-siphonage is the term applied to the backflow of used water, wastes and/or other matter into the city water supply system due to negative pressures being established in the city water distribution system or parts thereof.

(d) *Maximum Possible Water Level.* Maximum possible water level is defined as the maximum possible height to which water can rise in a fixture before it flows out freely into the open atmosphere through adequate size openings so designed as not to be obstructed by debris or waste matter. In numerous fixtures, such as bath tubs, lavatories, toilet bowls, drinking fountains, industrial tanks, etc., where the overflow does not discharge into the open atmosphere or is not of adequate size, the rim level of the fixture shall constitute the maximum possible water level.

(e) *Safe Air Gap.* A safe air gap is the minimum distance of a city water inlet or opening above the maximum possible water level of a fixture

or device to which city water is supplied, in order to prevent back-siphonage or backflow of the contents of the fixture or device into the city water distribution system. For circular openings the safe air gap shall be not less than two (2) times the inside diameter of the city water inlet pipe above the maximum possible water level. For openings other than circular the safe air gap shall be not less than two and one-quarter (2¼) times the square root of the area of the opening.

(f) *Acceptable Vacuum Breaker.* An acceptable vacuum breaker is a device intended for the prevention of back-siphonage or backflow of contaminated water, sewage or any other matter into the city water distribution system, and which has been tested and accepted by laboratory approved and recognized by the State Plumbing Board for testing such devices.

Sec. 3.—*Cross-Connections Between Water Supplies Prohibited.* No person, firm or corporation shall, in any manner, make or allow the existence of any direct physical connection for any purpose whatsoever between the pipes or conduits carrying water supplied by the Ann Arbor City Water Department and any pipes, conduits, fixtures or other devices carrying water supplied from a secondary source as defined in Section 2 (b) of this ordinance. Whenever necessary to supply city water to a system of pipes, conduits, fixtures or other devices conveying or containing water from said secondary source the city water system shall be protected against the backflow of the water from such secondary source by a safe air gap, as defined in Section 2 (e) of this ordinance.

Sec. 4.—*Notification of Existence of Secondary or Dual Supplies.* All persons, firms or corporations maintaining secondary or dual water supplies shall notify the Ann Arbor Water Department of their existence.

Sec. 5.—*City Water Supply Required to Certain Plumbing Fixtures.* All devices where persons normally come in direct contact with water shall be supplied with city water wherever city water is available. Piping and valves shall be so arranged that the supply to fixtures may be shut off in order to facilitate the quick tracing of the water supply to any one fixture.

Sec. 6.—*Warning Signs.* All openings in the secondary water supply system from which water may be obtained shall have at all times a metal sign prominently posted within two feet of the opening bearing the following warning:

WARNING
UNSAFE WATER
DO NOT DRINK

Such signs shall be at least 8 in. × 10 in. in size, prominently lettered in contrasting colors, with no letters less than 1 in. in height. Signs are to be furnished and maintained by the person, firm or corporation owning the secondary supply.

Sec. 7.—*Color Code.* Whenever deemed necessary for the protection of the city water system in buildings having a secondary or dual water supply, the Ann Arbor Water Department shall have the right to require that all exposed piping be painted distinguishing colors and so maintained that each pipe may be readily traced in its entirety by such colors. The colors required shall be bright blue for city water piping and brown for piping conveying water from a secondary source. In instances where the bright blue color or the brown color conflict with already well established color code in a

particular building the use of other colors of equal brightness and contrast may be allowed.

Sec. 8.—*Prohibited Direct or Indirect Connections With Drainage Systems, Sewers, etc.*

(a) In order to prevent the back-siphonage or blackflow of sewage or waste, or any other matter into the city water distribution system, no connection shall be permitted between the city water system and any drainage system, sewer system or any soil waste pipe, except as hereinafter provided.

(b) No plumbing fixture, device, valve, fitting, apparatus or plumbing connection of any kind shall be installed which will cause a connection between city water supply system and any sewerage or waste system, or that will permit or make possible by back-siphonage or backflow the introduction of sewage, waste or any other matter into the city water distribution system. The water supply to certain fixtures may be protected against back-siphonage or backflow by the use of acceptable vacuum breakers as provided in Section 9 (b) of this ordinance.

Sec. 9.—*Submerged Supplies, Protection Against Back-Siphonage and Prohibited Fixtures.*

(a) *Submerged Inlets.* No submerged city water inlets shall be permitted to tanks or other plumbing fixtures or devices except as hereinafter provided. To prevent the back-siphonage or backflow of the contents of said tanks, or other plumbing fixtures or devices, city water shall be introduced to same through a safe air gap as provided in Section 2 (e) of this ordinance.

(b) *Use of Vacuum Breakers.* If the city water inlet cannot be raised the safe air gap distance above the maximum possible water level of a tank, or other plumbing fixture or device, an acceptable vacuum breaker must be installed on the discharge side of the control valve in such manner than no back-siphonage is possible under any degree of negative pressure in the water lines and with water in the tank, or other plumbing fixture or device, at the maximum possible water level. The vacuum breaker shall be installed above the maximum possible water level of a tank, or other fixture or device, a vertical distance specified for the type of vacuum breaker used. For positive protection each such tank, or other plumbing fixture or device, must be provided with an individual vacuum breaker.

(c) *Toilet Bowls With Flushometer Valves.* Toilet bowls and other fixtures using flushometer valves must be equipped with an acceptable vacuum breaker installed on the discharge side of the flushometer valve. The bottom of the vacuum breaker shall be not less than four (4) inches above the flood rim of the fixture.

(d) *Flush Tanks—Back-Siphonage Prevention.* Every flush tank operated by a ball-cock, hereafter installed, shall have an acceptable vacuum breaker located not less than the safe air gap distance above the overflow outlet of such flush tank.

(e) *Drinking Fountains.* Drinking fountains shall be equipped with an inclined jet having the orifice completely protected with a safety guard and shall have the orifice not less than one-half ($\frac{1}{2}$) of an inch above the overflow rim.

(f) *Required Air Gaps on Common Plumbing Fixtures.* The minimum required air gap between the orifices of the faucet and the rim level of a common plumbing fixture hereafter installed shall be as follows:

Lavatories	1 inch
Kitchen sinks and laundry tubs	1½ inches
Bath tubs	2 inches

(g) *Flexible Hoses—Protection Against Back-Siphonage.* Basins or other waste fixtures supplied with a flexible hose whose outlet may drop below the rim of the fixture shall be equipped with an acceptable vacuum breaker installed in an acceptable manner on the discharge side of the control valve.

(h) *Frost-Proof Fixtures.* Installation of frost-proof water closets, drinking fountains, hydrants or other such fixtures shall be prohibited unless the city water supply is completely protected against any possible pollution due to back-siphonage of seepage water or any other waste matter.

(i) *Check Valves.* Check valves in and of themselves shall not constitute an approved safety device for the purpose of preventing back-siphonage or blackflow.

(j) *Special Fixtures.* All water supply equipment and appliances serving special fixtures shall conform with the intent and purpose of this section. Any special use for water as for air-conditioning equipment, refrigeration equipment, hydraulic elevators, presses, fountains, lawn sprinklers, dental cuspidors and aspirators, hospital equipment, automatic washing machines, automatic and other dish washers, restaurant equipment, laundry equipment, etc., shall be installed in such a manner so as to prevent back-siphonage or backflow either by the use of a safe air gap or an acceptable vacuum breaker.

Sec. 10.—*Right to Inspect.* Any employee of the city of Ann Arbor duly authorized to make inspections shall be granted entrance to any building or premises at any reasonable hour and be permitted to inspect or reinspect the plumbing and drainage system of the building or premises for the compliance with the provisions of this ordinance.

Sec. 11.—*Enforcement.* It shall be the duty of the plumbing inspector to enforce the provisions of this ordinance.

Sec. 12.—*Penalty for Violation.* The city of Ann Arbor shall have the right to discontinue or deny water service for non-compliance with any provision of this ordinance, and any person violating any of the provisions of this ordinance shall, on conviction thereof, be punished by a fine not to exceed $100 and costs of prosecution, or by imprisonment in the county jail for a period of time not to exceed 90 days, or both such fine and imprisonment in the discretion of the court.

Sec. 13.—*Validity.* Should any section, paragraph, phrase or provision of this ordinance be declared by the courts to be invalid, the same shall not affect the validity of the ordinance as a whole or any part thereof other than the part so declared invalid.

Sec. 14.—*Repeal of Previous Ordinances.* All ordinances or parts of ordinances in conflict herewith are hereby repealed.

Sec. 15.—*Date of Effect.* This ordinance shall be in effect on and after ten days from legal publication.

Passed December 17, 1945.

Cross-Connections and Back-Siphonage

By Andrew T. Dempster

Assoc. San. Engr., Dept. of Health, Detroit, Mich.

Presented on Sept. 20, 1945, at the Michigan Section Meeting, Grand Rapids, Mich.

ANY fictitious narrative about something which might naturally occur and from which a moral may be drawn is called a parable. Cross-connections and the problems of back-siphonage unfortunately are not fictitious, but in order to draw a moral from a paper on this subject, the discussion may be presented as a parable.

The parable begins with the establishment of a new chemical manufacturing plant and its satellite city of workers on wasteland located in one of the western states. Construction began in 1939 on this plant, which was to help supply Great Britain with TNT, gelatin and other chemicals used in explosives.

Layout of Plant

The plant was built by the DuMore Chemical Company, large-scale manufacturers of chemicals and explosives. The president of this company, E. Tyrus Phosa, or Ty Phosa, as he was generally called, had dreamed of building a model explosive chemical plant for many years. The plant and city would be a realization of his dream, and no money was spared to carry out some revolutionary ideas that Ty Phosa had wanted to try for so long.

A noted city planner laid out the city on undulating ground that lent itself to rather attractively curved streets. The houses were all individually designed, with nothing of the sameness of most factory towns, and where the houses were not located on high ground, the basement floor of the house was set above the normal grade level and the excavated material from the streets and other structures was graded around the houses so that the sewers, when over-taxed, would overflow to lower ground levels instead of into the new basements. The city was provided with beautiful parks along the Coliform River, and the new stores erected in the area designated as the business section were of modern construction and attractive in every respect.

Because the plant was the reason for the city's existence, the water supply was pumped from the Coliform River and processed and treated by the chemical plant. The chemical plant was designed by the company chemical engineers, and no expense was spared to make it the most modern and efficient plant of its kind in the world. This location was chosen because of the abundance of clear and sparkling soft water flowing into the Coliform River from the nearby mountains. The gelatin plant and the acid plants needed a good supply of pure water, so the ultimate in that direction was sought, and the chief chemical engineer finally convinced E. Ty Phosa that the distillation of the Coliform River water would provide the plant with the per-

fect solution to its wants. By the use of distillation equipment slightly larger than that needed to supply the plant, the domestic water supply problem for the workers would also be solved. This type of municipal supply would be unique, and the city of Colibank could truthfully advertise its water supply as the purest in the world. A part of the extra cost of this type of supply could be charged to advertising, since journal after journal would carry accounts of the pure drinking water provided for the employees of the DuMore Chemical Company. The plant was really to be a monument to E. Ty Phosa's many years of successful administration of the DuMore Chemical Company, and he accepted this idea with a great deal of enthusiasm.

The plant and city were completed in 1940. By that time World War II was no longer called a "phony" war, and Great Britain was pushing the DuMore plants hard to produce more and more explosives. It almost goes without saying that some difficulty was experienced in launching the Colibank plant into production.

Problems Encountered

One of the difficult problems to solve was the method of operating the distillation apparatus. The water was distilled three times, first by distilling from steam at 600-lb. pressure, then condensing and redistilling at progressively lower temperatures and pressures, until the last condensing operation brought the water down to almost river water temperature. This was accomplished by river water flowing through the condensers countercurrent to the distilled water flow direction. The heated condenser water was then used as boiler feedwater and as a feedwater supply to the distilling apparatus so that the greatest possible efficiency could be effected.

Carry-Over of Gases

Trouble was experienced from carry-over of gases, such as carbon dioxide, formed from the breakdown of the bicarbonates in the river water used. The eductors in the condensers could not remove all of the carbon dioxide; consequently some of it redissolved in the distilled water. This made the water somewhat acid and, as will presently be seen, caused considerable trouble.

The homes of the workers were finished before the plant was completed and water service had to be started as soon as possible. Samples from the distribution system were sent to the state health department laboratory for analysis. The gross contamination which was reported startled the plant's laboratory staff because they had expected a favorable report. The state in which the plant was located was sparsely populated and not much supervision was given to water plants; but after analyzing these samples, the state health department requested that the water main distribution system, which was probably badly contaminated during the construction period, be disinfected with chlorine, and that a bacteriological laboratory be set up in the plant to control the bacterial quality of the water supply. In the interim it was necessary to boil the water used by the residents until disinfection of the mains was satisfactorily completed.

E. Ty Phosa reluctantly complied with the request, and after an outside contractor spent several weeks disinfecting the mains with chlorine, the water was declared safe for drinking. The new residents rejoiced that it was

no longer necessary to boil their drinking water, and the company posted signs at the main highway entrances to the city proclaiming that Colibank had the purest drinking water supply in the world. When the citizens of Colibank stopped boiling their water, they were surprised to find that it still tasted a little flat, and refrigeration was necessary before it was palatable.

Red Water Problems

There were no plumbing codes in the state and the only regulations applying to the city were company regulations. Consequently, black iron pipe was used in the new hotel water piping system, and red water problems started in the hot water system soon after it was placed in service. This condition was corrected by installing a bypass feeder on the hot water system and by using sodium silicate solution in the feeder to prevent further corrosion of the black iron pipe.

Turbidity

Two weeks went by and the plant engineering staff congratulated themselves on how well they had planned the water service. Then a severe rain and electrical storm stopped the pumps in the pumping station; however, service was restored in a few minutes. The next day many workers at the plant complained about turbid drinking water and collapsed copper hot water tanks in their homes. These complaints were investigated by one of the plant engineers, who found that they were not at all exaggerated. He noticed, however, that all the collapsed tanks were located in houses on high ground elevations, and it was easily deduced that these tanks were collapsed by the existence of a partial vacuum in the water system. It followed that, when the pumps stopped operating, the water in the mains drained to the lower points in the system and created a partial vacuum at the highest points in the system.

An explanation for the turbid water was not found, however, until the investigator noticed that some homes on high ground did not have collapsed tanks. Searching further for the reason, he found that air relief valves were located at the high points on the distribution system where the mains continued on to lower points, and the location of these valves coincided with the undamaged tanks. An inspection showed that many of the valve pits had water in them, but the level was always below the air relief outlet. No doubt the water in these valve pits was the source of some of the turbid water when the supply pressure failed, and the resultant vacuum siphoned it back into the system through the air relief ports.

Further reflection showed that the blow-off connections to the sewer on the low points of the lines could also be subjected to partial vacuums, and any leaking blow-off valves would possibly allow sewage to be siphoned into the water system during periods of negative pressures.

The bacteriological laboratory at the plant reported that several samples collected from the distribution system after the interruption of the supply showed gross contamination, and once again the residents were cautioned to boil their drinking water.

Investigations by Engineers

President Phosa of the DuMore Company, who now made his residence at Colibank, became very much perturbed, because the drinking water of Colibank had already been advertised

far and wide for its remarkable purity. He, therefore, directed two engineers to chase down this trouble and provide a solution, so that a recurrence of contamination in the water supply would be impossible.

The engineers soon found that this problem was much discussed in water works and plumbing trade journals as well as in public health journals, but the solution was not so simple as it had seemed at first. It was discovered that all of the new plumbing fixtures in the town were of a type that would cause contamination of the water supply if negative pressures occurred in the water system.

At that somewhat late date the lately instructed engineers began to assemble a little library. They found hundreds of pages of well-packed data. They learned to know exactly what were cross-connections, inter-connections and backflows. They found that a great deal of effort, research, legislation and inspection was the rule with many states endeavoring to protect their systems. They learned of multifarious, nefarious mechanical gadgets and human thoughtlessness—some even that were not apparent in Colibank—which menaced the health of populaces. Amazing to them was a sample ordinance which they found and which, without every last detail for local application, amounted to a few dozen pages. They even found, imagine it, consulting engineers and sanitarians and officials of water works all giving of their time to produce co-operatively reports and practical suggestions for the proper treatment and safe distribution of public water supplies.

They found that plumbing regulations and codes were being revised in the more progressive cities of the country to provide protective devices which would preclude the possibility of "back siphonage" or "backflow."

The principles involved in this protection had been determined in plumbing laboratories, in universities and in several city laboratories. Obviously when a vacuum exists in a water supply pipe whose discharge end is submerged in a vessel of water which is possibly contaminated, the impure water will flow back into the supply pipes. Therefore, if the supply pipe is raised above the surface of the water, the possibility of backflow into the potable supply will be eliminated. If the discharge end is not raised high enough above the water surface, however, siphonage will still take place, since a partial vacuum is present at the outside of the pipe end and the water surface conforms to the pressure conditions above it. It has been determined that unless the pipe or discharge orifice is raised two internal pipe diameters above the water surface a water spout forms which allows the non-potable water to be siphoned into the potable supply system. It must be assumed that the water surface is at the highest level that the water can reach in a fixture or tank if and when the normal overflow outlets are not functioning.

It was found that it is not always possible to raise the supply above the water surface in certain types of equipment, such as developing tanks and rinse tanks, where bottom supplies are imperative for purposes of circulation. The answer to this problem was the mechanical or venturi vacuum breaker. The venturi vacuum breaker uses the principle of a venturi tube with air inlets provided on the downstream side of the venturi throat. Under normal flow, with the vacuum breaker placed above the highest possible water level of the fixture served, the water goes

through the throat at a velocity high enough to prevent the water from leaking out of the air inlets. When vacuums occur in the water supply system, the air inlets relieve the vacuum below the venturi throat so that the water rises only an inch or two in the tail pipe above the water level of the fixture.

The mechanical vacuum breaker uses the same principle of air relief, but utilizes check valve disks so that under pressure the air inlets are closed, while under vacuum the air inlet disk is off its seat, and a mechanical check valve, acting as a constriction in the path of normal flow, throttles the amount of air being drawn back from the now open air inlet sufficiently to prevent the rise of more than 1 or 2 in. of water in the tail pipe. These two check valve disks are usually connected together mechanically, so that one cannot work unless the other one is also functioning.

The barometric loop was found to accomplish the same function. This loop of pipe, with the top at least 35 ft. higher than the water level, provides a barrier so that a perfect vacuum on the supply side cannot induce siphonage of non-potable water from the downstream side of the loop even though it is submerged in non-potable water. The two investigators also learned that when a potable and a non-potable supply were connected together a cross-connection resulted which could become dangerous at any time the non-potable supply pressure increased beyond the pressure of the potable supply. The only safe answer to this problem was to separate the two systems completely and color code the piping so that new connections would not be made too readily between the two systems.

Engineers' Report and Recommendations

The engineers presented a report based on their new-found knowledge, recommending that either all submerged potable supplies be raised two pipe diameters above the highest possible water level in the fixture or an acceptable vacuum breaker be inserted in the supply pipe at least 6 in. above the highest water level in the fixture, with a control valve upstream from the vacuum breaker to insure that it goes through one operation sequence each time the valve is opened or closed. They recommended further that all air relief valve pits be drained properly and that the air relief ports be extended above the grade level at each pit. All blow-offs were to be blanked off from the sewers or indirectly discharged to the sewers through a sufficient air gap.

Their report also included an item on chemical treatment of the hot water system in the Colibank Hotel. When the supply failed, the bypass feeder quickly filled up the hot water pipes with sodium silicate, which in turn had badly gummed up the coffee urn in the dining room. The only solution was either to discontinue treatment or to find a non-siphonable chemical feeder. Flushometer and tank toilets were condemned if they did not have vacuum breaker protection. Several cross-connections between river water lines and distilled water lines in the plant were specified as very dangerous, and it was pointed out that these connections must be broken. The most notable one was a bypass connection around the distilling apparatus from the river water pumps, which was deemed necessary in the event anything happened to the still. The report pointed out, however, that when the still was out of service,

the people should not drink raw river water, so it was suggested that a chlorinator be placed on the bypass line, with the bypass disconnected from the distilled water pump suction line by swiveling the suction line to connect to either the still or the chlorinated river water line, but never to both lines at the same time.

Following the report, the arguments between the engineering staff and the president were really heated, but in the end the recommendations were accepted because enough had already happened to Colibank to prove that contamination of the water supply could and did occur. Work was immediately started to eliminate all of these hazards.

Later Discoveries

For the remainder of the first year of operation nothing serious occurred, except that the collection of an unsafe water sample from a frost-proof hydrant led to the discovery that there was one piece of equipment they had forgotten. This sample started another investigation, which disclosed that these frost-proof hydrants had ground drains which opened up automatically when the water supply was turned off. When the ground water level became higher than the drain level, the first water to come out of the hydrant was ground water; consequently all ground or sewer drains on fire hydrants, frost-proof park hydrants and frost-proof drinking water fountains were sealed.

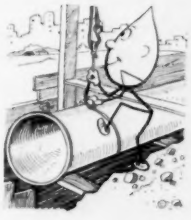
The water and fire departments of Colibank discovered several more ways of collapsing copper hot water tanks. During the first big fire in town the pumps on the new fire-fighting trucks were operating under vacuum on the suction lines from the hydrants. The next day they found that they had effectively collapsed several hot water tanks in the vicinity of the fire. The water department found that the same effect could be produced either by shutting off a section of water main for repairs or by having a main break, which would cause a high velocity in the main and result in a vacuum at a point in the main upstream from the break.

The medical department of Colibank made the greatest discovery, however, almost one year from the day the city started to function. They were suddenly besieged by workers and their families calling for medical aid on what appeared in most cases to be a severe attack of diarrhea or dysentery. Two weeks later they had a typhoid epidemic on their hands. Before they were through, 200 cases of typhoid were recorded in this city of 4,000 persons.

The source of the typhoid was traced to the water supply, and here is found the moral of this parable. All of the tubing, valves, tanks and condensers which made up the distilling apparatus were found to be badly corroded because of the corrosive quality of the distilled water. The condenser tubes that carried river water were found to be leaking and large quantities of this contaminated river water were mixing with the distilled water in the bottom of the condensing chamber. The leakage had done its damage before the daily water analysis had revealed this condition. Unfortunately the river water had by then become badly contaminated, since a new government munitions plant had been built upstream on the Coliform River. This completed the necessary conditions for the spread of typhoid organisms by this "perfect" water supply.

Today the city of Colibank has a conventional water filtration plant lo-

cated a short distance upstream from the city. The distilling apparatus is used only for plant process water now. Mr. E. Ty Phosa sees to it personally that the chlorine demand of the potable water is satisfied and an excess is carried, so that the residual all over Colibank is 0.4 ppm. Although all the known cross-connections have been eliminated, he does not want to discover any more the way the last one was discovered. The signs reading "Colibank, the City With the Purest Water Supply in the World" have been changed to read "Colibank, Public Water Supply Approved."



Inspection of Water Works Materials

By H. Arthur Price

Asst. Specification Engr., Dept. of Water & Power, Los Angeles, Calif.

Presented on Oct. 23 and 25, 1945, at the California Section Regional Meetings, Los Angeles and Berkeley, Calif.

ON glancing through the Index of the A.W.W.A. publications from the year 1881 to the present, the author was greatly surprised to see that there had been no papers prepared on the subject of "Inspection." Following up, a few neighboring water companies were telephoned and asked how much inspecting they did. They replied: "Not much." When asked why not, they stated: "We trust in the integrity of the manufacturer."

This is a tribute to the manufacturer, but it is believed that inspection should be viewed in the light of a co-operative service—a check—a further service augmenting the manufacturer's own inspection.

The government has been the largest purchaser in the United States for the past few years, and, in line with its policy of rigorous inspection, methods have been established for controlling the uniformity of products and the rejection of inferior materials. Manufacturers have become accustomed to government inspection and uniformity has been the result. Most purchasers desire uniformity, and that can be achieved only by inspection control and by properly drawn specifications.

To cover properly the subject of inspection, it will be necessary to approach the subject from the standpoint of testing and specifications, and in this connection reference will be made to requirements and procedures in the water system of the Department of Water and Power of the city of Los Angeles.

Cast-Iron Pipe

The Department's requirements closely follow those of Federal Specifications WW-P-421, with the exception of cement lining and dimensional and tolerance requirements.

Occasionally cast-iron pipe arrives in the Department's yard in a car that has had rough handling and in which the dunnage has not been properly prepared (Fig. 1). This has caused the pipe to slide, shift and rotate, resulting in some sections being damaged. All this requires inspection, including hammer testing and the examination of the spigots and bells of those sections that do not ring true. The latter can be accomplished either with a magnifying glass or by applying turpentine over the surface in question and then dusting the surface with cement or powdered chalk, which clearly shows the location and extent of the crack.

A hydrostatic testing machine which will handle full lengths of pipe is often used.

A scratch tester has been devised to test the hardness of cement linings (Fig. 2). It consists of a phonograph needle, ground off to $\frac{1}{64}$ in. at the end, and a spring arrangement giving read-

FIG. 1. Car Shipment of Cast-Iron Pipe Showing Broken Dunnage

ings in pounds. The scratch tester is drawn perpendicularly along the lining and the force exerted to produce a scratch is observed in pounds. Four pounds is the minimum reading allowed for cement linings under the Department's specifications. An inspector soon "catches on" how to use the scratcher. Judgment must be used, however, as sometimes there is a skin of laitance which cannot be considered. Pipe is ordered with an approximate thickness of lining of $\frac{1}{8}$ in. The cement used must meet the "Merriman Test" (described later) and no seal coat is permitted.

With regard to the weight of pipe, yard men and inspectors closely watch the weight of each pipe, which is marked on the inside of pipe by the manufacturer, and those sections which are close in weight to the minimum weight allowed are set aside and reweighed. Occasionally, sections of pipe are rejected.

Cast-Iron Castings

Cast-iron water works fittings, manhole and meter covers, and other castings are fabricated for the Department on the West Coast. Foundry practice is excellent; nevertheless inspection is necessary. Inspectors check accuracy of patterns and work between the foundry and the Department in adjusting changes in drawings required by casting problems. Wall thicknesses of fittings 12 in. and over are checked for eccentricity.

Manhole and meter box covers and frames are checked for fit. Class 30 iron, 30,000-psi. tensile strength, under A.S.T.M. Specification Designation A

48, is specified for the majority of castings.

Under these specifications there are different size test bars: Test Bar A qualifies castings having thin sections; Test Bar B qualifies average size castings; and Test Bar C qualifies castings of very heavy sections. Under the specifications no provision has been made for the minimum deflection of the test bar at the breaking load. Deflection is a measure of the ductility, and ductility is a desirable quality in castings—the more ductile the less brittle. After observing the deflection of test bars on cast-iron castings for several years, the Department inspectors found that the deflection of good iron was in direct proportion numerically to the breaking load. The Department's specifications now include a requirement for deflection, which is: The deflection in inches at the breaking load shall not be less than $\frac{1}{10,000}$ numerically of the breaking load in pounds. For example:

Test Bar A fails at 1,150 lb., the deflection cannot be less than 0.115 in.

Test Bar B fails at 2,200 lb., the deflection cannot be less than 0.22 in.

Inspectors watch castings as they are processed through the foundry. Occasionally over-zealous foundry men hide flaws in castings by using "Smooth On." Alert inspectors must be in the right place at the right time.

The Department requires hydrostatic testing of all cored fittings 12 in. and under (Figs. 3 and 4). Pipe and valves are hydrostatically tested, and, to be consistent, why shouldn't cast-iron fittings be tested? During the war, due to lack of foundry help, only occasional hydrostatic testing was required.

In regard to coatings for the fittings, the inspector must see that the fittings are preheated prior to dipping, that the coal tar pitch is the right consistency, and that the castings are double-dipped.

Valves

Valves introduce the subject of pre-purchase inspection. The Department specifications covering this item are quite rigid, for example: double disc valves must have all bronze internal working parts; the stem nut must be one and one-half times the diameter of the stem; and there are other requirements too numerous to mention. A manufacturer desiring to do business with the Department submits drawings of the valves he proposes to furnish, and the details are checked on a "valve

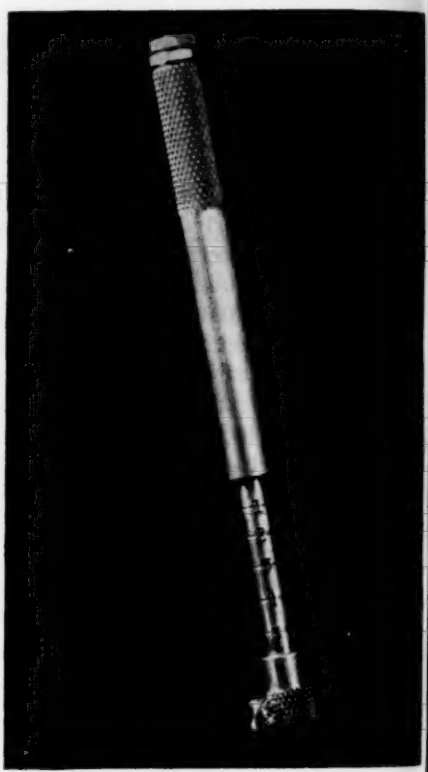


FIG. 2. Scratch Tester for Determining Hardness of Cement Linings

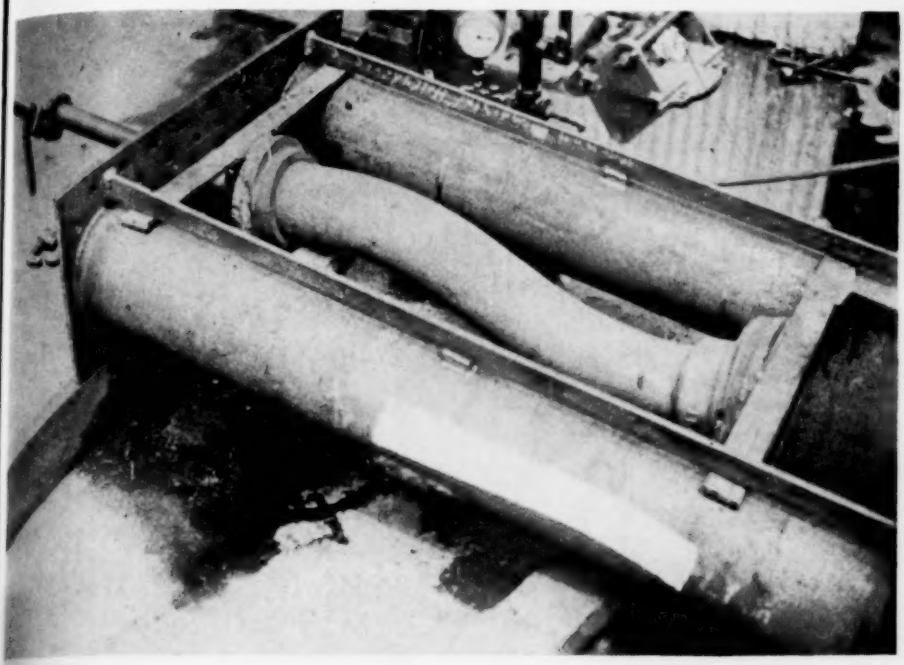


FIG. 3. Hydrostatic Testing of an Offset

check sheet" (Fig. 5). After all changes are made so that the valves conform to the specifications, the drawings are approved by the Chief Engineer of Water Works and Deputy General Manager. After this, the manufacturer makes up a sample valve and ships it to the Department for testing. Valves are tested from fully closed to fully open at 175 psi., free discharge (Fig. 6). The valves are evaluated on the basis of dryness, ease of operation in opening and closing, and their physical condition after the test. Some brands of valves tested were absolutely inoperative and others were very hard to operate, chewed the seats and leaked after the test. After the sample valve satisfactorily passes the test, valves of the same manufacture, which meet the requirements of the specifications, are acceptable for purchase. Inspection of the valves after purchase is merely cursory. Occasionally a valve is opened and closed to check for ease of operation, or it may be taken apart to check the castings.

The preceding method applies for regular valves in the line. When valves are bought for a special application, especially if the size is large, they may be taken apart, the castings inspected and the discs tested for deflection. In some instances, the Department has discovered large valves which had on the inside defects involving considerable repair work, and which, if they had not been properly inspected, would have been inoperative in service.

Galvanized Pipe

Inspection of galvanized pipe consists principally of seeing that the pipe

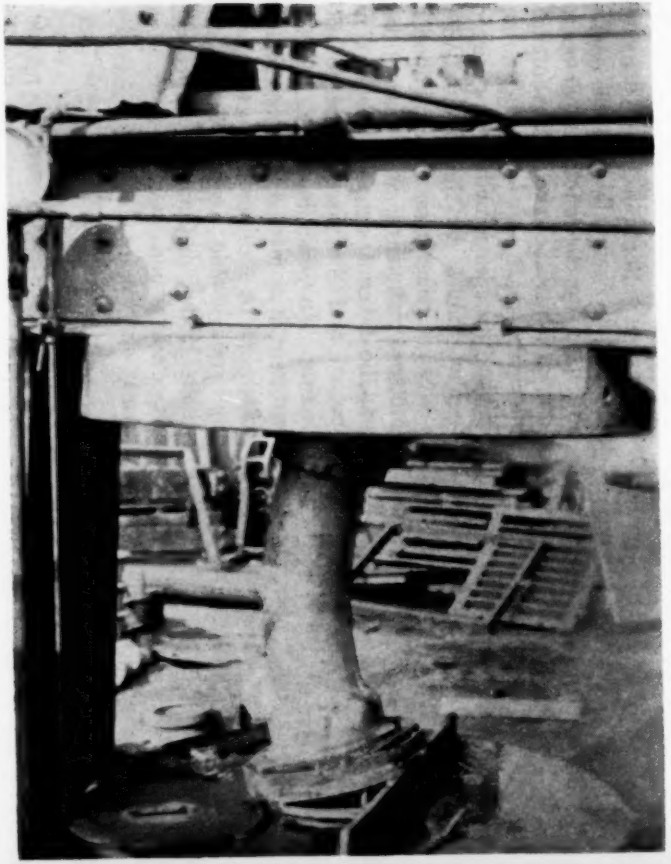


Fig. 4. Hydrostatic Testing of a 45° Ell

BUREAU OF WATER WORKS & SUPPLY

SPECIFICATION COMPLIANCE
FOR
GATE VALVES

*MAKE _____ *SIZE _____ DATE _____

DISK _____ (Double - Wedge) ENDS _____ (Hub - Flg. - Screw) *W.W.P _____ PSI SPEC _____ (136-MC-R1; 117-MC-R3)

GEARS _____ (Bevel - Spur) BY PASS _____ (Size) *H.T.P. _____ PSI P.O. _____

[1]REMARKS _____

WEIGHT _____ LBS.

LENGTH, O.A. _____ IN.
" BY-PASS TO NUT _____ IN.

[4]HEIGHT, O.A. _____ IN.
" C.L. TO TOP _____ IN.

GEAR RATIO _____
TURNS TO OPEN _____

IRON, CLASS _____ A.S.T.M
TENSILE _____ PSI

DISC: MATERIAL _____
[3]TENSILE _____ PSI

STEM: MATERIAL _____
[3]TENSILE _____ PSI
THREAD _____ ACME _____ IN.
DIAMETER _____ IN.
[4]DIAM. COLLAR _____ IN.
THICK. COLLAR _____ IN.
LENGTH OVERALL _____ IN.
LENGTH UNDER COLLAR _____ IN.

STEM NUT: MATERIAL _____
[3]TENSILE _____ PSI
GRIP (1½ DIAM STEM) _____ IN.

SEAT RINGS: MATERIAL _____
[5]TENSILE _____ PSI
(NO LUGS UNDER 12") _____

OTHER INT. PARTS _____
MATERIAL _____
[3]TENSILE _____ PSI

	HUB	FLANGE	SCREW
THICK.	____ (9/16 or 7/8)	THICK. ____	STD. PIPE ____
O. D.	____	O. D. ____	O. D. ____
DEPTH	____ (4" min.)	B. C. ____	CNFD. ____
I. D.	____ (2" Min.)	NO. HOLES ____	DIAM. HOLES ____ (1250 or 2500 Std)

THICKNESS OF BODY _____ IN.
" OF BONNET _____ IN.
" OF BONNET FLGS. _____ IN.
HEX. BONNET NUTS _____

ALEMITE (GEAR BEARINGS) _____
GREASE CASE (IF SPEC.) _____

OPER. NUT, 2" x 2" _____ LEFT ARROW _____

PACKING _____ (161-S-RE) SIZE _____

STUFF. BOX SLOTTED, LONG BOLTS _____ CLOSED, SHORT BOLTS _____
[4]DEPTH _____ IN.
LINED _____
EVERDUR WASHERS _____

PACKING BOLTS: MATERIAL _____
[4]SIZE _____ LENGTH _____
HEAD _____ HEX. NUTS _____

COATING (RUST RESIST.) _____

TESTS OR MISC. _____

* INFORMATION TO BE CAST ON VALVE.
1 RISING STEM, SPECIAL ENDS, MOTOR OR HYDRAULICALLY OPERATED, ETC
2 DOUBLE DISC - 38000 psi; SOLID WEDGE - 36000 psi.
3 55000 psi MINIMUM.
4 INFORMATION NOT REQUIRED IN SPECIFICATIONS.
5 36000 psi MINIMUM.

Fig. 5. Valve Check Sheet

FIG. 6. Hydrostatic Testing of Valves—175 lb. Free Discharge

ends are protected with thread protectors and that the pipe is properly galvanized. A.S.T.M. Specifications are very liberal in this respect and have had to be tightened to meet the Department's requirements. A.S.T.M. Specification Designation A 120-44 specifies:

> The weight of zinc coating shall be not less than 2.0 oz. per sq.ft. of total coated surface. The weight of coating expressed in ounces per square foot shall be calculated by dividing the total weight of zinc, inside plus outside, by the total area, inside plus outside, of the surface coated.

Exaggerating, of course, it is possible under these requirements to obtain pipe with an outside coating weighing 4 oz. per sq.ft. and the inside bare. This pipe would average 2 oz. per sq.ft. of surface and would therefore meet the specifications. Inasmuch as it is desired to have galvanizing on both surfaces, it has been specified that on mill shipments of pipe the galvanizing, both inside and outside, shall strip not less than 1.75 oz. per sq.ft. of surface. Inspection and testing have resulted in several carloads being rejected. When local out-of-stock galvanized pipe is purchased, it is specified that the galvanizing shall strip not less than 1.50 oz. per sq.ft. on both inside and outside surfaces.

Lumber

When large quantities of lumber are purchased, an inspector is sent to check the lumber prior to delivery. Douglas fir is ordered to meet particular grades as stated in Standard Grading and Dressing Rules of the West Coast Lumbermen's Association, and is required to be grade-marked. Redwood is ordered to meet the requirements of

the California Redwood Association. If an inspector is at the yard at the time the lumber is sorted and graded, lumber graders are not prone to include lumber that is on the border line of being inferior grade.

Fire Hydrants

Inspection of fire hydrants includes checking the castings, quality of iron, finish work of brass and the coating, as well as checking the outlet threads with "go" and "not go" gages. Particular attention is required on the 4-in. outlet threads, as they are not a National Standard. The Department has made "go" and "not go" gages for this size and has loaned them to manufacturers to duplicate. Each manufacturer has his own variations in these thread dimensions and they vary considerably. A coupling has sometimes been used as a gage.

Copper Service Fittings

Inspection of copper service fittings is a timesaver to the installation crew. The number of bad fits is negligible. Inspectors check machine work, fittings with ragged threads are thrown out and threads are checked with "go" and "not go" gages. The weight of the fittings is also checked, a 3 per cent tolerance being allowed. A chemical analysis is made to determine compliance with the chemical composition requirements.

Steel Pipe

No attempt will be made to cover inspection of steel pipe, as inspection procedures can be easily set up by reviewing A.W.W.A. Standard Specifications 7A.3 and 7A.4, which cover both mill and electric-fusion-welded steel pipe.

Asbestos-Cement Pipe

Asbestos-cement pipe is purchased under the Department's specifications, which require, in addition to the regular 800-lb. hydrostatic shop test, a hydrostatic destruction test of one section from each one hundred sections of pipe. Department inspectors observe the various steps in the manufacture of asbestos-cement pipe and certify to its compliance with the requirements.

Cement

Cement has received considerable attention in the past few years due to surface deterioration of a number of water works structures over the United States. As a result, the Department specifications for cement include that cement shall meet a sugar solubility test, which test was devised by Thaddeus Merriman, formerly Chief Engineer of the New York Board of Water Supply. This test determines whether the cement clinker is underburned. Underburned clinkers result in cement that does not produce durable concrete.

Personnel

This discussion would not be complete unless some consideration were given to a proper inspection organization and to the qualifications of inspection personnel, their authority, responsibility and relationship with the manufacturer.

The inspection organization of the Department's water system is set up on rather ideal lines. Inspection is conducted under the direction of the Engineer in Charge of Testing Laboratories, which section is independent of the other divisions and reports directly to the management. The regular inspection force handles the usual inspections; however, when there is particu-

ar need to draw on personnel in other divisions who are particularly qualified to inspect some article or process, they are made available for such inspection. In this way the Inspection Section has the service of a number of engineers, construction men and others with wide experience in various fields.

The qualifications of an inspector may be summed up by saying that he should have both practical experience and some knowledge of the engineering principles involved in his particular assignment. On the general inspection of metals he must know that test coupons are, at best, but indicators of the general characteristics of metals, owing in most cases to their favorable location with regard to defects. The inspector should be familiar with the physical characteristics indicated by a fractured test bar or coupon. Familiarity with the several types of testing equipment and testing procedure may also be essential. This includes knowledge of how such equipment may be calibrated, the effect of improper test procedures on the results, and the effects of size and shape of test piece. For inspection of machined parts, the inspector must be familiar with the construction and use of gages.

Certain traits of character are highly desirable. The inspector should be straightforward and prompt, should be possessed of good judgment, tact, a sense of fairness and the ability to act fairly and firmly without arousing undue antagonism. Principally, judgment is required.

The book "Testing and Inspection of Engineering Materials" by Davis, Trozell & Wiskocil (McGraw-Hill, New York, 1941. 372 pp.), includes a description of the many necessary qualifications for inspectors.

The inspector's primary responsibility is to see that the work is performed in accordance with the specifications. He further may serve in expediting the delivery of material. His authority should include the necessary stoppage of work, if such work is not being done in accordance with the specifications, and he should have the authority to require the removal or repair of faulty material.

The manufacturer is entitled to complete the work at the lowest possible cost. By co-operating with the manufacturer the inspector will aid in reducing the manufacturer's cost. Occasional changes in the specifications develop, resulting in savings both to the manufacturer and the purchaser.

Carvin's Cove Water Supply Project for Roanoke, Va.

By Louis R. Howson

Alvord, Burdick & Howson, Engrs., Chicago, Ill.

Presented on Nov. 8, 1945, at the Virginia Section Meeting, Roanoke, Va.

THE bringing in of the Carvin's Cove water supply will terminate thirty years' experience with periodically recurring inadequacy at Roanoke. The initial development will add 150 per cent to the safe yield of the present supplies and, with comparatively minor additional expenditure, this can be extended to 300 per cent. This development will provide Roanoke with an unexcelled water supply with a hardness of approximately 20 ppm. and located at such an elevation as to be available by gravity.

In order to assist in a better understanding of the Carvin's Cove development, this discussion will briefly review some of the factors affecting the design, such as the population growth of the past and that projected for the future, the future water requirements, the capacity of the present sources of supply and their deficiencies, and the additional capacity needed to provide adequately for the future water requirements of Roanoke. Brief reference will also be made to the various alternative sources of increased water supply available to Roanoke and the factors which influenced the selection of the Carvin's Cove supply over the other available sources.

Population Growth

Inasmuch as the use of water depends primarily upon the growth in population, consideration was first given to the past and probable future population growth at Roanoke (Fig. 1). In the 40-year period prior to 1930, Roanoke experienced a rapid and sustained population growth. Like most other cities its population growth in the next decade was practically zero. This was followed by the war period with its effect upon population concentration in cities. It is believed that following the termination of the war the normal upward trend which was affected by the depression and the war will be resumed and that the present population of approximately 76,000 will increase to 85,000 by 1950, 100,000 by 1960 and 130,000 by 1980.

Water Consumption

Based upon the forecasted population and study of the water consumption for average and maximum days, a forecast of water requirements for the future was made. A study of the past consumption disclosed that there were a number of periods during which restrictions on use affected particularly the maximum rates and the ratio of maximum to average. The average day's use was also affected by a waste survey made in 1931 which reduced the pumpage nearly 1 mgd. and the fact that the Norfolk & Western Railroad, about 1920, had found it necessary to develop an independent supply in order

to be assured of adequate water for its needs.

The forecast for the future should, of course, be based upon the assumption that an adequate supply will be available. On that assumption it is

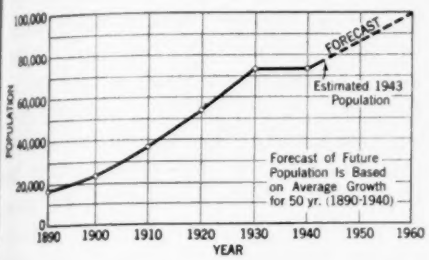


FIG. 1. Chart Showing Past and Estimated Future Population of Roanoke, Va., Including Vinton, Va.

estimated that the average day will increase to: 7.2 mgd. in 1950, 9.0 mgd. in 1960 and 12.2 mgd. in 1980, with the maximum day 50 per cent above these figures.

The forecast of the average and maximum days up to 1960, together with the recorded experience of the past, is shown on Fig. 2.

Present Sources of Supply

The safe yield of any water works is measured by its ability to deliver during periods of minimum availability. The present water supply of Roanoke is obtained from a number of widely scattered sources. The principal supply is secured from Crystal Springs, located not far from the center of the city, which has a dependable dry weather flow of somewhat less than 4 mgd. During the dry period of 1945, Crystal Springs yielded but 3.6 mgd.

Additional springs, known respectively as Muse, River and Smith, are used as auxiliary supplies. These are scattered about the city and in 1937 were estimated to have a total dependable yield of about 1.3 mgd.

About 30 years ago the Vinton water supply was merged with the Roanoke supply. Impounding dams on Falling and Beaver Creeks northwest of Roanoke are able to deliver a safe yield of 1.5 mgd. into the system by gravity. This water passes through pressure filters and marble beds for stabilization in order to reduce corrosion.

In a further effort to increase the supply the private water company drilled wells near Crystal Springs. There are two such wells which, pumped jointly, have a safe yield of 400,000 gpd. The water which they furnish is high in iron and very hard.

The total safe yield of all existing supplies is 6.8 mgd., a figure which fails by more than 2.5 mgd. to meet the maximum demand of the present time, and which would only be one half of

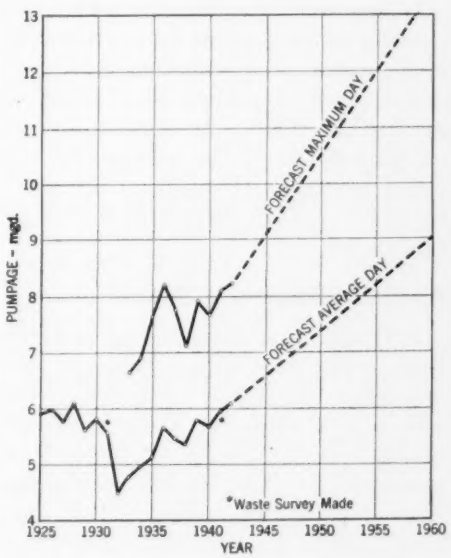


FIG. 2. Chart Showing Past and Estimated Future, Average and Maximum Days of Pumpage—Roanoke, Va.

the maximum demand reasonably anticipated fifteen years hence.

Additional Capacity Required

In comparing the forecasted requirements and the safe yield of the existing supplies it is apparent than an increased supply is urgent. On the assumption that all of the existing supplies would be retained in service, the capacity of a new development need be sufficient only to supply the difference between the maximum day's demand and the maximum safe yield of all the present supplies. It is believed, however, that with the development of an adequate supply of high quality the wells, and quite probably the springs, other than Crystal Springs, will eventually be abandoned. With the assured adequacy and the 20-ppm. hardness of the new supply it is also hoped that the Norfolk & Western Railroad may find it to its advantage to purchase water again from the public supply.

It was recommended that additional capacity be provided at the present time to the extent of at least 6 mgd., which, it was estimated, would be adequate to as late as 1960. It was, however, recognized that in the selection of the future supply for Roanoke, at this time, the more remote future must also be considered.

Available Sources of Supply

Although Roanoke has long suffered from severe periodic inadequacies, the deficiency has largely been due to the failure to develop the water resources of the area rather than to the lack of availability. The area has an average rainfall of approximately 40 in. per year. There are numerous watersheds within reasonable distance of Roanoke which could be developed for Roanoke's needs. Possibly it was this abundance of supplies which to some measure delayed the ultimate development. Both the city and the private company (for the water works system of Roanoke was privately owned until 1938) had made a number of investigations looking toward an enlarged future water supply. Two reports made for the city some 20 years ago recommended taking water from the upper Roanoke River. The company had selected Carvin's Cove, first brought to the attention of the management by Charles E. Moore, and reported upon favorably by Sanborn & Bogart, consulting engineers of New York, and Dr. Chas. P. Berkey of Columbia University, who reported upon geological features as affecting storage and dam construction. It should be stated that prior to 1932 there were no accurate U.S. topographic maps of the area available and it was probably for that reason that Carvin's Cove had escaped attention for so long.

In 1936 the private company authorized Alvord, Burdick & Howson to make a study of all practicable sources and to advise relative thereto.

The map, Fig. 3, shows the various practicable sources of supply available to the city of Roanoke and their relationship geographically to the city itself and to each other.

Each of these supplies was investigated as to water yield, cost of construction and annual cost of operation, as well as to the quality of water that would be delivered.

Analyses of the Carvin's Cove water showed a total hardness of 20, methyl orange alkalinity of 10 and an iron content of 0.1 ppm. The Roanoke River sources showed a hardness of approximately 145 ppm., with methyl orange alkalinity from 100 to 120, color normally ranging from 5 to 18 and

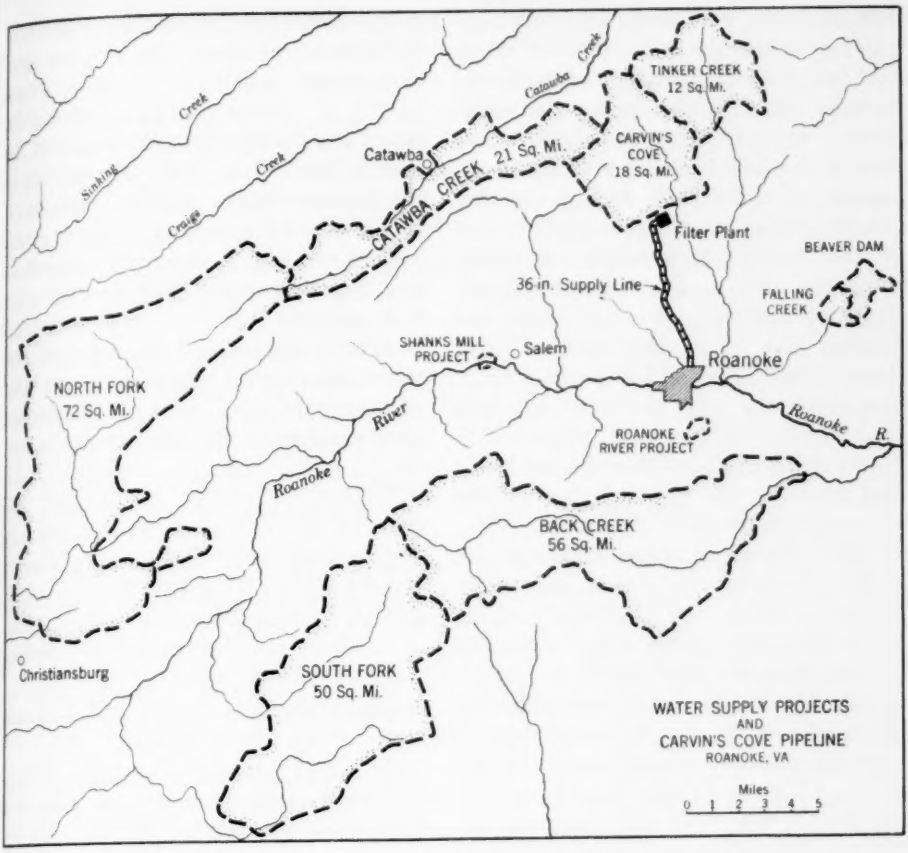


FIGURE 3

iron from 0.17 to 0.30 ppm. North Fork had the hardest water at 220 ppm.

The estimated construction and annual costs of these projects are:

Project	*Construction Cost*	*Annual Cost*
Carvin's Cove	$1,908,242	$149,600
North Fork	3,251,000	279,600
South Fork	3,606,100	291,300
Back Creek	1,811,700	206,000
Shank's Mill	1,530,500	178,100
Roanoke River	712,000	134,400

The estimated construction costs varied from $712,000 for Roanoke River, developed at a site in Roanoke, to $3,600,000 for South Fork, with Carvin's Cove intermediate at $1,900,000, of which $600,000 had previously been spent by the company, leaving the additional expenditure of $1,300,000 to bring the water to the city. In annual costs, which include interest and depreciation as well as operating cost, Roanoke River at Roanoke and Carvin's Cove were approximately one-half that of North Fork, South Fork or Back Creek, and materially less than Shank's Mill on the Upper Roanoke River.

The Roanoke River (at Roanoke) project, while lowest in both first and

annual costs, was dropped from consideration because the sewage of Salem and much of the sewage of Roanoke entered the Roanoke River above the water works pumping station and would continue to do so through storm water overflows even though the dry weather flow were intercepted.

The Carvin's Cove supply was, therefore, the next in line from the standpoint of both cost of construction and annual cost. As that supply was of lowest hardness and Carvin's Cove possessed the best reservoir site and was capable of future enlargement at lowest cost, its development was clearly indicated as the best solution of the Roanoke water supply problem.

The city of Roanoke acquired the water works by condemnation in 1938. Nothing further was done with respect to a new supply until 1943, when the city of Roanoke authorized an investigation for the purpose of determining the most practicable means of purifying and bringing the Carvin's Cove water to Roanoke and, in conjunction therewith, the most advantageous extent and location of storage reservoirs to improve distribution and pressures throughout the city. The report was completed in October 1943.

In making this investigation a more detailed study of the ultimate capacity of the Carvin's Cove project was undertaken. The concrete dam had been built in 1928. Much of the land which would be flooded at pool stage had not been acquired at that time. The reservoir when filled to the spillway level would store 6,470 mil.gal. at elevation 1,170 ft., whch is 34 ft. above Mill Mt. reservoir which now floats on the city distribution system. This amount of storage is very large in proportion to the 17.88 square miles of drainage area tributary above Carvin's Cove dam.

The relation between the elevation of the water behind the dam and the storage volume in billion gallons is shown in Fig. 4. From this figure it will be noted that, while the total height of the dam is more than 70 ft., 50 per cent of the capacity of the storage reservoir is in the top 15 ft. below spillway level.

The yield of a reservoir project is not directly proportional to the reservoir capacity. It is a combined result of several factors, including runoff and its uniformity of distribution, volume of storage in relation to runoff, surface area exposed to evaporation, etc.

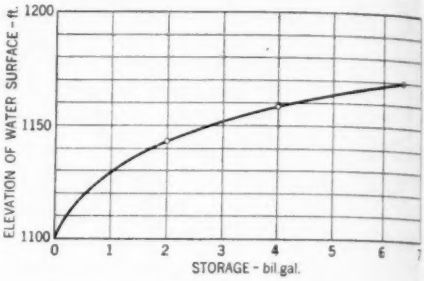


FIG. 4. Chart Showing Relation Between Water Elevation and Storage Volume of Carvin's Cove Reservoir—Roanoke, Va.

There were no records of runoff from Carvin's Cove itself and, accordingly, engineering studies were made of the runoff characteristics of 24 streams located within a radius of 125 miles of Roanoke and for which flow records were available through the United States Geological Survey. The daily, monthly and annual average flows were studied and from these the coefficient of variation from the mean of flows in this general area was computed. Using these data by means of the Hazen method of comparing such records it was determined that in the driest year likely to occur once in a cycle of 20 years the yield of the Carvin's Cove project would be not less

than 10 mgd. after allowance for evaporation and all other losses. For all other years a much larger yield can be obtained.

The yield of 10 mgd. is estimated with the full 6,470 mil.gal. of storage available. With a smaller storage the yield would be less but it would not be decreased in anything like the proportion to the reduction in storage. For illustration, as indicated on Fig. 5, if the storage volume was but 4,000 mil. gal. instead of 6,470, the yield would still be 9 mgd. or but a 10 per cent reduction below that at full capacity. If the storage was but 2,000 mil.gal. the yield would still be 7.5 mgd. over the driest period to be expected once in a 20-year cycle. Reducing the reservoir capacity by the 70 per cent which is provided by the Carvin's Cove dam reduces the yield but 25 per cent.

These facts suggested the study of the practicability of bringing in water through diversion from other watersheds without the necessity of providing storage on those watersheds but rather by utilizing the Carvin's Cove storage to greater advantage.

The Carvin's Cove project is unique in that it lends itself to progressive development by diversion from adjacent streams to such an extent that the water requirements for Roanoke can be met for the indefinite future. Investigations showed that by the construction of a small diversion dam built across Tinker Creek (Fig. 3), whose drainage area adjoins Carvin's Cove on the east, and a tunnel through the dividing ridge, the runoff from this additional drainage area of 12 square miles can be diverted into Carvin's Cove and with no change in the existing dam or reservoir capacity the yield can be increased thereby from 10 to 15 mgd. (Fig. 5).

By further similar construction of a low diversion dam on Catawba Creek whose drainage area adjoins Carvin's Cove on the west, the runoff from an additional 21 square miles can likewise be diverted into Carvin's Cove, thereby increasing the yield of the present reservoir another 5 mgd., making the total yield of the three watersheds using

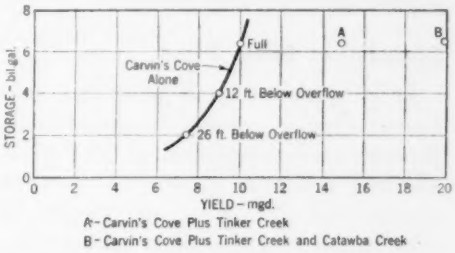


FIG. 5. Chart Showing Storage vs. Yield—Carvin's Cove Project—Roanoke, Va.

Carvin's Cove storage 20 mgd. This yield will be available 19 years out of 20 after allowing for evaporation and permitting a small dry weather flow to pass through the diversion dams on Tinker Creek and Catawba Creek at all times.

When combined with the present sources of supply, the total yield of the Carvin's Cove-Tinker-Catawba development would amount to 27 mgd., an amount four and one-half times the average requirements of the present and twice the estimated average annual requirements of 1980. The present supplies of Carvin's Cove alone, without the Tinker-Catawba addition, will provide materially more water than will be required by Roanoke till 1980.

It is apparent that the water requirements of Roanoke can be met with no enlargement of the present reservoir capacity for a time well beyond any date for which it is reasonable to forecast. This results from the fact that it was practicable in the construction of

Carvin's Cove dam to build a structure in a narrow gorge at reasonable expense and to obtain thereby the elevation necessary for gravity flow to Mill Mt. The over-development of storage was somewhat incidental to getting the elevation. The wisdom of that conconstruction becomes apparent in connection with the development being made nearly two decades later.

Location of Filter Plant

It is apparent from what has preceded, that it would be practicable, through careful selection of filter plant site and selection of pipeline sizes, to operate the Carvin's Cove supply by gravity most of the time. Therefore, in selecting the site of the filter plant, a careful study was made of the topography between Carvin's Cove dam and the city. A site was selected which is located at approximately elevation 1,150, at a level about half way between the full reservoir stage at Carvin's Cove and the distribution reservoir full stage on Mill Mt. The city acquired an entire farm of approximately 85 acres on which this site was located.

The project consists of a 36-in. pipeline from the Carvin's Cove dam to a 6-mil.gal. filter plant located approximately 3,000 ft. south of the dam. From the filter plant a 36-in. main will connect to the city distribution system, including a 24-in. feeder connecting to an existing 16-in. main which will feed in both directions one line leading directly to Mill Mt. reservoir.

The project includes a reinforced concrete roof over the present Mill Mt. reservoir, the construction of an additional 2-mil.gal. reservoir at City Farm in the southwest section of the city, and the construction of a 2-mil. gal. steel standpipe located in the northwest section of the city. In effect, including the 2-mil.gal. clear well at the filter plant, there will be a storage reservoir of approximately 2 mil.gal. located at each of the four corners of the distribution system.

The filter plant is of the conventional mechanical gravity type of 6-mgd. capacity. The water from Carvin's Cove which provides "oversize storage" should be of very low turbidity. Filters are designed on 2 gal. per sq.ft. rating, with all hydraulic design based on operating at 50 per cent overload.

The storage in the top 12 ft. of Carvin's Cove reservoir will be available to the plant by gravity after it is once filled. That storage will amount to over 2,500 mil.gal. and when once filled will provide a minimum yield of about 9 mgd. There will therefore be no necessity for low-lift pumping for many years after the reservoir is filled.

On reaching the filter plant the water will be flocculated for approximately 45 minutes after receiving the chemical dosage, and will then be settled in a two-compartment settling basin having a total detention period of three hours at the 6-mgd. rate.

From the settling basins the water will pass to the four 1.5-mgd. filter units, grouped two units on each side of a central gallery. The influent is at the back of the filters, as is the wash water duct, thus providing a very capacious pipe gallery with all equipment easy of access.

The effluent from the filters is through ducts which unite and discharge to the 2-mil.gal. clear well, the water being chlorinated on leaving the filters.

The 2-mil.gal. clear well is of 20 ft. depth, the mid-depth being at the same elevation as the full elevation of Mill Mt. reservoir. This elevation is such

that when the filter plant is operating the top half will normally be in use and at times when Crystal Springs is furnishing the entire supply the lower half only will be available for storage.

Facilities for feeding alum, lime, carbon and chlorine are provided. Because the filter plant will be remote from railroad connections, chemicals will probably be received in containers and facilities for unloading and storage are provided on that basis.

The plant is so designed that it can be enlarged progressively as needed to the ultimate capacity of the Carvin's Cove development, namely, 18 mgd.

Selection of Pipeline Capacity

The size of pipelines from Carvin's Cove dam to the filter plant, and also from the filter plant to its connection to the present city distribution system, are influenced somewhat by the relative elevations of Carvin's Cove dam and existing facilities. Over 35 per cent of the storage in Carvin's Cove is in the top 12 ft. of the reservoir. This amount of storage will provide a safe yield of 9 mgd. in connection with the Carvin's Cove drainage area, from which it is apparent that once the reservoir is filled it can operate by gravity with no low-lift pumping required for the next 25 years more or less. With adequate clear water storage at the filter plant, the rate of flow between the dam and the filter plant will be the average rate for the 24 hours a day. Hourly fluctuations will be taken care of by storage in the clear water reservoir. A 30-in. pipeline would have been adequate for this 3,000 ft. but in order to make available by gravity more of Carvin's Cove water this line was made 36 in.

Between the filter plant and the Roanoke distribution system, the pipeline

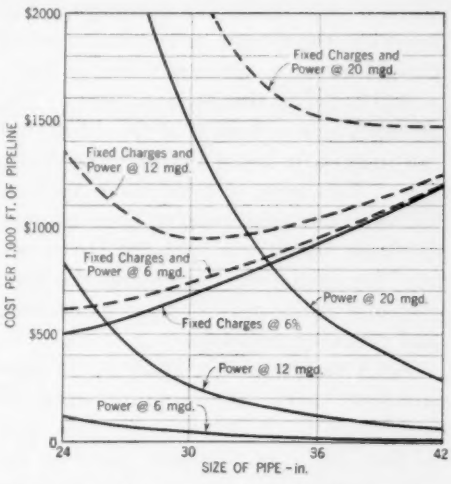


FIG. 6. Chart Showing Pipeline Fixed Charges vs. Power Costs—Roanoke, Va.

will be required to carry peak rates of draft except as modified by Mill Mt., City Farm and Carroll Avenue reservoirs. The distance is approximately 35,000 ft. A study of the economical size of pipeline for this reach was made and the results are shown on Fig. 6.

The annual cost of a pipeline consists of interest and depreciation on the investment, plus the cost of power required for pumping against the friction in the pipeline. Obviously the larger the pipeline the greater its initial cost and the greater the annual fixed charges. Also, the less will be the friction and the less the pumping cost.

This exhibit shows in diagrammatic form the annual cost, consisting of fixed charges and depreciation, and the power cost to pump against pipe friction and their use in determining the economical size of the Carvin's Cove transmission line. The diagram shows the total annual cost for 24-, 30-, 36- and 42-in. diameter pipe, under pumpage rates of 6, 12 and 20 mgd. The low point on each of the total annual cost curves shows the most economical

size for that particular pumpage. For instance, the 6-mgd. curve is lowest at the 24-in. size, although nearly horizontal between the 24- and 30-in. The 20-mgd. rate is lowest at the 42-in. but not materially lower than for the 36-in. size. This type of analysis is applicable in evaluating gravity lines as well as those which are supplied by pumping, for obviously decreasing the pipe size will make gravity flow inadequate and pumping necessary.

As a result of this analysis, in conjunction with the requirements of maximum hour delivery on that part of the line from the filter plant to the city distribution system, the ultimate development of 18 mgd. and a consideration of the difficulties incident to the duplication of the line in the fairly remote future, it was recommended that the line be 36 in. in diameter.

Plans and Specifications

Complete plans and specifications were submitted to the War Production Board late in 1944, but, although the plans and specifications met with their entire approval, it was not until about the middle of 1945 that the board considered the war demands for critical materials sufficiently relaxed to authorize construction. The City Council then promptly called for bids for construction, and they were received on Aug. 20, 1945.

Filter Plant

The dimensions of the filter plant building were those dictated by utility requirements. The dimensions in plan and elevation having been determined, however, there was as always considerable latitude concerning the type of architecture to be selected. Several alternative designs were made, each built around the same measurements for the building proper and each costing substantially the same. The city selected a southern Colonial type believed particularly suitable for construction at the site on what is known as "Old Plantation Road."

Storage Reservoirs

The topography served by the Roanoke water works, aside from the central business district, varies 200 ft. or more in elevation. The distribution system is quite deficient in feeder mains. The wide variation in topography, coupled with the deficiency in feeder mains, has necessitated the construction of numerous booster stations. There are now seven such stations operating on the system.

An analysis of the relative costs and merits of additional feeder main construction and of strategically located reservoirs demonstrated that the most economical expenditure of funds for the correction of distribution deficiencies would be by means of the construction of additional reservoirs. Mill Mt. now provides 2 mil.gal. of storage in the southeast corner of the city. The new Carvin's Cove clear well, to the northeast of the city, will provide from 1 to 2 mil.gal., depending upon the direction of flow. It was decided to build a 2-mil.gal. reservoir at City Farm, near the southwest section of the city, and to construct a 2-mil.gal. steel standpipe at Carroll Avenue, near the northwest section of the city. The effect of these four reservoirs at the four corners of the distribution system on intermediate pressures is illustrated in Fig. 7. The installation of these reservoirs will make unnecessary the operation of two pumping stations under ordinary conditions at least.

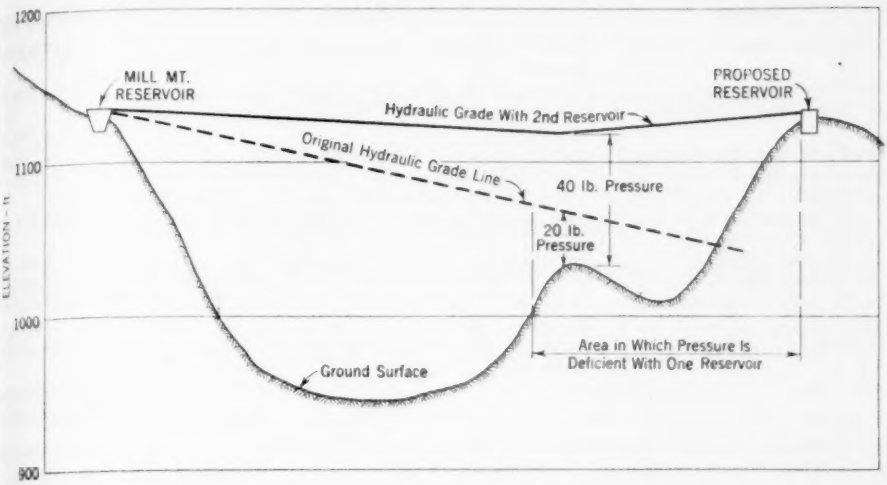


FIG. 7. Chart Showing Effect of Distribution Reservoirs on Pressures—Roanoke, Va.

Contracts

Bids were received for the construction on August 20, 1945. The work was divided under eight contracts. In general, it was found that the prices that were bid for materials and equipment were well in line with estimates previously made; the bids on filter plant structures were materially above the estimate and although but two bids were received for the pipe laying, these were from 50 to 75 per cent above the estimate of cost.

Alternate bids were taken on three materials for the 35,000 lin.ft. of main line from Carvin's Cove to the city limits, namely cement-lined cast-iron, steel cylinder reinforced concrete pipe, and steel pipe with bituminous spun lining and either bituminous coated or bituminous coated and wrapped exterior. Contract was awarded to the Lock Joint Pipe Co. for reinforced concrete pipe. Comparative prices were:

Steel cylinder reinforced concrete	$378,411.00
Steel coated and wrapped	$420,693.90
Steel coated only	$377,523.00
Cement-lined cast-iron	$450,811.30

In view of the fact that pipe would not be available for laying for 75 days after August 20, 1945, it was decided to readvertise the laying contract and endeavor to secure broader competition. New bids were taken on September 24. Six bids, varying from $637,742.50 to $658,704.37 were secured.

In view of the representative bidders submitting figures and the closeness of the figures submitted, the acceptance of the low bid was recommended in the belief that it fairly represented the cost of the work under existing labor conditions. Although the nearby Radford Ordnance Plant had recently released several thousand employees, contractors who thoroughly studied the situation were extremely pessimistic regarding the conditions under which labor would be available and the efficiency with which it would operate.

The amount of the contracts and the successful contractors for the entire work, other than Carroll Avenue standpipe and the covering of Mill Mt. reservoir, are as follows:

Contract	*Bidder*	*Amount of Bid*
A—Filter Plant Structures	Ralph E. Mills Co. and Blythe Bros. Co., Roanoke, Va.	$ 417,900.00
B—Filter Equipment	Roberts Filter Mfg. Co., Darby, Pa.	63,870.00
C—Pumping Equipment	Worthington Pump & Machinery Corp., Harrison, N.J.	4,260.00
D—Slow Mix Equipment	Jeffrey Mfg. Co., Columbus, Ohio	4,735.00
E—Pipe and Fittings (In City)	Lynchburg Foundry Co., Lynchburg, Va.	41,121.15
Pipe and Fittings (Carvin's Cove to City)	Lock Joint Pipe Co., East Orange, N.J.	378,411.00
F—Valves (Altitude)	Anderson Valve Corp., Scottdale, Pa.	2,290.00
Valves (Gate)	M & H Valve and Fittings Co., Anniston, Ala.	17,250.00
G—Pipeline Construction	Ralph E. Mills Co. and Blythe Bros. Co., Roanoke, Va.	637,742.50
H—City Farm Reservoir	Ralph E. Mills Co. and Blythe Bros. Co., Roanoke, Va.	96,700.00
	TOTAL	$1,664,279.65
Estimated cost of Carroll Ave. Standpipe		52,000.00
Estimated cost of Mill Mt. Reservoir Roof		60,000.00
	TOTAL	$1,776,279.00

Personnel

W. P. Hunter is City Manager of Roanoke. Charles E. Moore is Manager of the Water Works, a capacity in which he has served under both private and municipal ownership. Alvord, Burdick and Howson, Chicago, were consulting engineers for the water works project.

Acknowledgments

Acknowledgment is made of the fine co-operation by various local citizens and engineers, particularly W. P. Wiltsee, Chief Engineer of the Norfolk & Western Railroad, whose knowledge of construction conditions and service on committees in connection with the project were very valuable.

Erratum

In "Development and Practice of Municipal Water Softening" by H. M. Olson (Jour. A.W.W.A., **37**: 1002 (1945)):

On p. 1002, second paragraph—for Ventura, Calif., read *La Verne, Calif.*

On p. 1006, second paragraph—for Ventura, Calif., read *La Verne, Calif.*

Fuller Explanation: The large plant serving 2,000,000 population in the Los Angeles area is located at La Verne. About 70 miles northwest of Los Angeles is Ventura, a city of 20,000 which has a chemical precipitation plant treating water from the Ventura River for the city of Ventura supply only. The La Verne plant, processing water from Boulder Dam, is one of two chemical precipitation-zeolite plants operating on municipal supplies.

A Wartime Capital Improvement

By W. S. Mahlie and Uel Stephens

Chemist-in-Charge, Filtration Plant, Fort Worth, Tex.

Supt., Water Works, Fort Worth, Tex.

Presented on Oct. 16, 1945, at the Southwest Section Meeting, Shreveport, La.

THE wartime problems of the Fort Worth Water Works were undoubtedly very similar to those of every other water works located in a greatly congested war activity center. One of the several measures inaugurated to save manpower at Fort Worth was the mailing of the 53,000 monthly statements instead of having them hand delivered. This expedient saved four employees, three of whom were assigned to other duties.

Another conservation measure, which was adopted during the summers of 1943 and 1944, was the voluntary rationing of water for lawn sprinkling. Through the medium of the press, customers were requested to conserve water so that the department would be able to meet the peak demands. The response was splendid. As a result of asking, *not* demanding, those persons who lived in even-numbered houses to confine their lawn and garden sprinkling to Mondays, Wednesdays and Fridays, and those living in odd-numbered houses to water on alternate days, with no restrictions on Sundays, water consumption was reduced by approximately 5.8 mgd.

Capital Improvement

An item of capital improvement, which was made primarily to meet the increased demands due to the war impact, but which will serve equally well as a permanent part of the plant, was the installation of additional elevated storage and supply mains.

Early in 1943 it was believed that the only way to meet the increased summer demands was to install additional pumping equipment. A preliminary investigation indicated the need for a pumping unit of 15-mgd. capacity, operating under an average head of 270 ft., and a 900- to 1,000-hp. motor. Inquiries indicated that the best delivery date to be expected would be from 18 to 24 months, which would not be in time to alleviate the situation during the summer peak, which was only 6 or 7 months away. Other studies were commenced with the aid of Freese and Nichols, Consulting Engineers of Fort Worth. The result of the investigation indicated that the problem might be solved, at least partially, by the addition of storage space and the installation of larger mains leading away from the pump station. This solution appeared especially attractive, since during the past 6 or 7 years, it had been necessary gradually to increase the pressure at the station gage from 90 to 115 psi.—a condition which was placing the distribution system under dangerously high pressures, resulting in frequent breaks.

Materials for concrete storage and cast-iron pipe for mains could all be obtained with reasonably low priorities and delivery could be made in a few months. With these considerations in

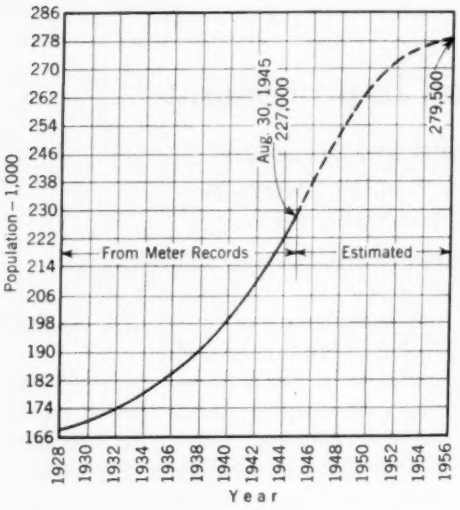


FIG. 1. Population Curve of Fort Worth, Tex.—Connected Population (4.3 Persons per Connection)

mind, as well as the population curve (Fig. 1), plans were developed and construction was begun on two storage reservoirs and feeder mains.

Usage studies of meter books and pumpage records, terrain investigations, trends of population directions and other data available indicated that the storage should be located in the extreme north and south sections of the city. (Figure 2 shows the location of the two reservoirs with respect to the main pumping plant and the business district.) Main capacity to the North Side was decidedly deficient, while leading into the South Side there were 3,000 ft. of 36-in., 6,600 ft. of 30-in. and 2,045 ft. of 20-in. pipe which could be used as part of the main to serve the South Side reservoir. Hydraulic studies of the two projects were made simultaneously and the designs prepared accordingly; however, due to financial, governmental and construction conditions, it was necessary to construct them at different times.

The South Side project was designed in January 1943 and approved by the War Production Board in March 1943, which assigned it a priority rating equivalent to AA-3. Because reinforcing steel was very critical at that time the design embodied gravity type walls and a minimum amount of reinforcing steel in the roof. By August 1943, when the North Side project was approved by the WPB, reinforcing steel had become available and a conventional reinforced concrete design for the North Side reservoir was adopted. An earth cover was placed completely over the South Side reservoir, while on the North Side the vertical walls extending some 18 ft. above ground were given simple architectural treatment.

Results of Improvement

It can be seen from Fig. 3 that the maximum water level in the two reservoirs is at approximately the same elevation. The elevation was fixed within narrow limits by two existing small elevated tanks and the safe pumping ceiling. The hydraulic computations necessary to establish reservoir capacities, dimensions and elevations, as well as main sizes and other essential details, were based on a modified Hardy Cross analysis of sections of the distribution system. An important consideration in the design of the reservoirs was the desirability of reducing the pumping pressures. How well this was accomplished can be determined from a study of Tables 1, 2, 3 and 4, which are individual pump performance records for peak or heavy days.

The main Holly pumping plant, located approximately in the center of the city, handles all of the water distributed to the 53,000 customers. The pumping equipment consists of one 8-

TABLE 1

Record of High-Service Pump Operation—Aug. 13—Peak Day for 1940

Hour	Pumping Rates—mgd.					Pressure psi.
	No. 1 15 mil. gal.	No. 2 15 mil. gal.	No. 3 8 mil. gal.	No. 4 12 mil. gal.	Total	
12 M.N.				9.6	9.6	92
1 A.M.				9.6	9.6	92
2				5.0	5.0	92
3				5.2	5.2	90
4				8.5	8.5	91
5		15.8		7.2	23.0	91
6		14.5		12.0	26.5	90
7		16.0			16.0	88
8		13.7		12.3	26.0	96
9	11.2	13.6		10.6	35.4	102
10	11.5	13.6		10.8	35.9	103
11	11.0	15.8		10.5	37.3	103
12 Noon		16.2	6.3	8.0	30.5	93
1 P.M.		13.8	8.2	10.5	32.5	101
2	12.4	13.2	8.0	7.6	41.2	104
3	13.2	14.0			27.2	103
4	14.0	14.8			28.8	100
5	15.0	12.8		10.8	38.6	106
6	12.5	11.7	7.4	11.0	42.6	108
7	11.6	12.0	7.8	10.4	41.8	106
8	11.0	10.5	7.6	10.2	39.3	110
9	12.5		8.0	11.0	31.5	106
10	13.7			12.0	25.7	100
11				6.4	6.4	94
12 M.N.				10.8	10.8	92
Maximum	15.0	16.2	8.2	12.3	42.6	110
Minimum	11.0	11.7	6.3	5.0	5.0	88

Total Pumpage: 25.41 mil.gal. Total Usage: 25.41 mil.gal.

TABLE 2

Record of High-Service Pump Operation—Aug. 4—Peak Day for 1944

Hour	Pumping Rates—mgd.					Pressure psi.
	No. 1 15 mil. gal.	No. 2 15 mil. gal.	No. 3 8 mil. gal.	No. 4 12 mil. gal.	Total	
12 M.N.	10.6	11.5		10.3	32.3	108
1 A.M.	11.3	11.5			22.8	110
2				11.0	11.0	94
3				11.3	11.3	94
4	12.4			11.8	24.2	103
5	13.2			12.0	25.2	100
6	13.3			8.8	22.1	102
7	14.6			10.9	25.5	98
8	15.6		9.2	13.0*	37.8	98
9	10.7	11.5	7.6	16.0	45.8	110
10	11.9	12.3	7.8	18.2	50.2	108
11	12.0	12.7	8.0	20.0	52.7	106
12 Noon	12.2	12.6	8.1	17.0	49.9	104
1 P.M.	11.6	12.1	8.1	18.0	49.7	106
2	11.7	12.2	8.0	17.2	49.1	105
3	13.3	12.0	7.9	18.0	49.2	106
4	10.2	10.7	7.5	17.0	45.4	109
5	9.7	10.2	5.0	15.6	40.5	111
6	9.0	10.7	5.1	18.5	43.3	110
7	10.2	11.0	7.6	16.2	45.0	108
8	11.0	12.0	7.9	18.8	49.7	105
9	11.9	12.6	8.1	18.0	50.6	103
10	10.0	10.1	7.4	18.2	45.7	110
11	8.8	9.5	7.2	16.0	41.5	110
12 M.N.		11.4		10.2*	21.6	110
Maximum	15.6	12.7	9.2	20.0	52.7	111
Minimum	8.8	9.5	5.0	8.8	11.0	94

* Steam pump in service 8:00 A.M. to 11:00 P.M.

Total Pumpage: 38.43 mil.gal. Total Usage: 38.43 mil.gal.

mgd., one 12-mgd. and two 15-mgd. electrically operated pumps and one 8-mgd. steam-driven pump, having a total designed capacity of 58 mgd. The steam unit had been abandoned in 1934 but had to be put back in service in July 1944 in order to meet the increased demands. All of the electric pumps discharge through individual Venturi meters and then into a common header. Because of interferences prevailing under high pressure it was not possible to produce more than 53 mgd.

Table 1 shows the pump operations for the peak day of 1940. At that time the average pressure was slightly below 100 psi. Pumps 1 and 2, which are rated at 15-mgd. capacity each, were seldom performing at the design ratings. In 1945 the summer demand for water was in general satisfactorily

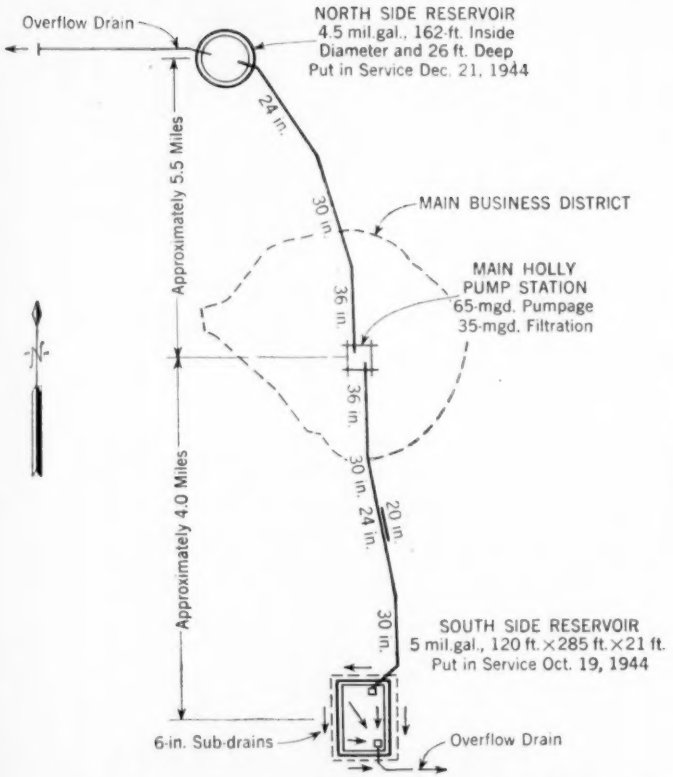


FIG. 2. Location Sketch Showing Storage, Mains and Pump Station—Fort Worth, Tex.

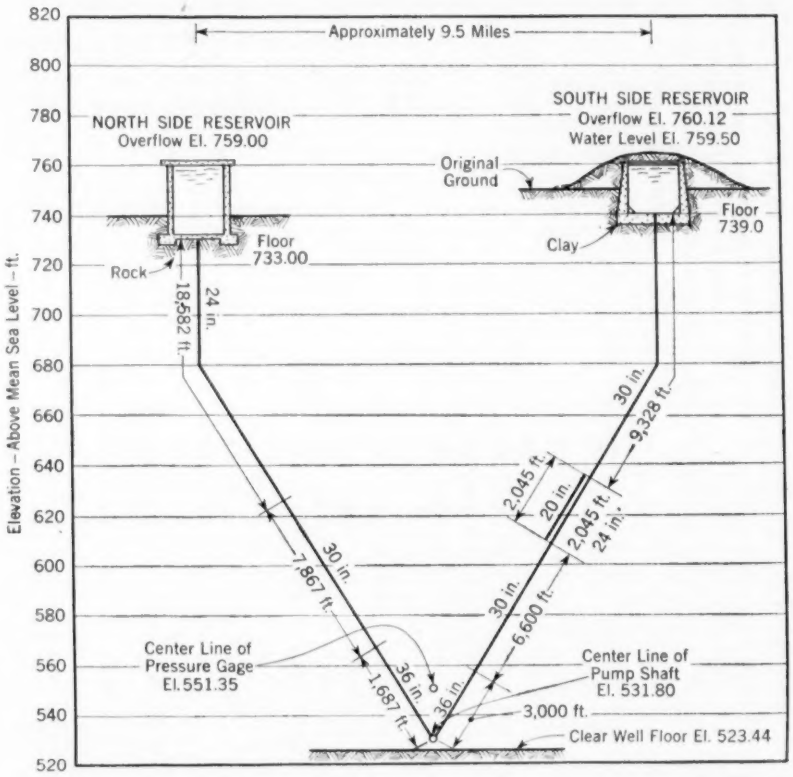


FIG. 3. Diagram Showing Reservoirs and Mains—Fort Worth, Tex.

TABLE 3

Record of High-Service Pump and Reservoir Operations—Aug. 4, 1945—Peak Day

Time of Observation	Pumpage Rates—mgd.					Pressure psi.	Reservoir Data			
							North Side		South Side	
	No. 1 15 mil.gal.	No. 2 15 mil.gal.	No. 3 8 mil.gal.	No. 4 12 mil.gal.	Total		Depth ft.	Elevation ft.	Depth ft.	Elevation ft.
12 Midnight	14.5		6.8	12.5	33.8	95	16¼	749.25	12¼	750.75
1 A.M.	14.4			12.5	26.9	95	16¾	749.75	12	750.50
2	14.8			11.0	25.8	95	18¼	751.25	13¼	751.75
3	14.5			10.1	24.6	98	19½	752.50	14¼	752.75
4	15.0			8.5	23.5	96	20½	753.50	15½	754.00
5	14.9			9.6	24.5	97	22	755.00	16	754.50
6	15.0			12.8	27.8	97	23	756.00	16½	755.00
7	14.2			13.0	27.2	95	23¾	756.75	17½	756.00
8		15.5	8.1	12.5	36.1	97	23¾	756.75	18¼	756.75
9		15.6	9.0	12.5	37.1	95	23¾	756.75	18¼	756.75
10		15.9	9.2	12.8	37.9	95	23	756.00	18	756.50
11		15.6	9.1	12.5	37.2	95	23	756.00	17¾	756.25
12 Noon		15.9	9.1	12.6	37.6	95	22¼	755.25	17¾	756.25
1 P.M.		15.9	9.1	12.8	37.8	95	21¾	754.75	17½	756.00
2		15.8	9.1	12.6	37.5	95	21½	754.50	17¼	755.75
3		15.9	9.1	12.8	37.8	95	20¾	753.75	17¼	755.75
4		16.1	9.1	12.9	38.1	95	20	753.00	17	755.50
5		16.0	9.1	12.9	38.0	95	19¼	752.25	16¾	755.25
6		16.2	9.2	13.1	38.5	94	19	752.00	16½	755.00
7		16.5	9.3	13.4	39.2	94	18¼	751.25	16	754.50
8	16.5		9.6	13.9	40.0	90	17	750.00	15	753.50
9	16.2		9.6	13.8	39.6	90	16	749.00	14	752.50
10	15.2		9.1	13.1	37.4	94	15½	748.50	13½	752.00
11	15.9		9.0	12.9	37.8	95	16	749.00	13¼	751.75
12 Midnight	14.4		5.5	12.6	32.5	97	16	749.00	12¼	750.75
Maximum	16.5	16.5	9.6	13.9	40.0	98	23¾	756.75	18¼	756.75
Minimum	14.2	15.5	5.5	8.5	23.5	90	15½	748.50	12	750.50

Total Pumpage: 34.35 mil.gal. Total Usage: 34.39 mil.gal.

Fig. 2. Location Sketch Showing Storage, Mains and Pump Station—Fort Worth, Tex.

Fig. 3. Diagram Showing Reservoirs and Mains—Fort Worth, Tex.

met, although there existed a few low-pressure areas from which some complaints originated.

Table 2 is the actual pumping record for August 4, 1944 (all-time peak day for Fort Worth) before the larger mains and reservoirs were put in service. The average pressure throughout the 24-hour period was over 105 psi., with the maximum of 111 psi. All pumps were delivering considerably below their designed capacities and consequently operating very inefficiently. The greatest pumpage rate, which was also the usage rate, due to the lack of storage, was 52.7 mgd. at 11:00 A.M. In order to supply this demand it was necessary to operate all five pumps.

Table 3 is the actual pumping record for Aug. 4, 1945, the peak day of that year. The two reservoirs and feeder mains were then in service. A study

TABLE 4

Record of High-Service Pump and Reservoir Operations—Aug. 21, 1945

Time of Observation	Pumpage Rates—mgd.					Pressure *psi.*	Reservoir Data			
							North Side		South Side	
	No. 1 15 mil.gal.	No. 2 15 mil.gal.	No. 3 8 mil.gal.	No. 4 12 mil.gal.	Total		Depth *ft.*	Elevation *ft.*	Depth *ft.*	Elevation *ft.*
12 Midnight	15.1			11.5	27.0	95	20¾	753.75	17	755.50
1 A.M.	15.5			8.5	24.0	93	20¾	753.75	16¼	754.75
2	15.5			8.2	23.7	93	21½	754.50	17¼	755.75
3	15.6		8.1		23.6	93	22½	755.50	18¼	756.75
4	15.5		8.5		24.0	93	23¼	756.25	18¾	757.25
5	15.4		9.1		24.5	93	24½	757.50	19¼	757.75
6	15.2		9.1		24.3	94	25¼	758.25	20	758.50
7	16.1		9.4		21.0	90	25¾	758.75	20¾	759.25
8		16.9	9.5		26.4	90	25	758.00	20¾	759.25
9		17.4	9.6		27.0	90	24¼	757.25	20	758.50
10		16.0	9.1	12.9	38.0	91	23½	756.50	19¾	758.25
11		16.1	9.1	13.0	38.2	91	23	756.00	19½	758.00
12 Noon		16.0	9.1	12.9	38.0	91	22¼	755.25	19¼	757.25
1 P.M.		15.9	9.0	12.9	37.8	91	21¾	754.75	19¼	757.75
2		15.9	9.0	12.9	37.8	92	21½	754.50	19	757.50
3		15.8	9.0	12.9	37.7	93	21	754.00	19	757.50
4		15.8	9.0	12.8	37.6	95	21	754.00	19	757.50
5		15.9	9.0	12.9	37.8	94	21	754.00	19	757.50
6		15.8	9.0	12.8	37.6	94	20¾	753.75	19	757.50
7		15.9	9.0	12.9	37.8	92	21	754.00	19	757.50
8	15.1		9.1	13.0	37.2	91	20¾	753.75	18¾	757.25
9	15.1		9.1	12.9	37.1	92	20¾	753.75	18¼	756.75
10	16.0		8.0	13.3	37.3	90	21	754.00	18¼	756.75
11	15.6			13.0	28.6	91	21¼	754.25	18¼	756.75
12 Midnight	16.0			10.5	26.5	91	22	755.00	19	757.50
Maximum	16.1	17.4	9.6	13.3	38.2	95	25¾	758.75	20¾	759.25
Minimum	15.1	15.8	8.0	8.2	21.0	90	20¾	753.75	16¼	754.75

Total Pumpage: 31.81 mil.gal. Total Usage: 31.11 mil.gal.

of individual pumping rates shows that each pump was at all times performing very near or above the designed capacities. The 1945 maximum pumpage rate of 40.0 mgd. occurred at 8:00 P.M. and at that time water was coming from the two reservoirs and being pumped into the mains at the same time. The usage rate of 50 mgd. was being supplied by three pumps, which had a rated capacity of 35 mgd., but which were working under favorable head conditions and producing at a 40-mgd. rate. The remaining 10 mgd. was backflow from the two reservoirs.

Pressure was maintained uniformly below 98 psi., with an average of about 95 psi. Thus, it can be seen that it was possible to reduce the average pressure from 105 psi. on Aug. 4, 1944, to 95 psi. on Aug. 4, 1945, maintaining the maximum under 100 psi. Even with

TABLE 5

Electric Power Pumping Cost (0.66¢/kwhr.)—Sept. 12, 1945

Pump No.	Pumpage, *1,000 gal.*	Kwhr. Used	Kwhr. per 1,000 Gal.	Cost per 1,000 Gal.	Total for Month		Kwhr. per 1,000 Gal.
					1,000 gal.	Kwhr. Used	
Aug. 4, 1944 Pressure: Maximum 111 psi., Minimum 94 psi.							
1	10.190	12.700	1.25	0.82¢	265.840	331.100	1.29
2	8.370	10.800	1.29	0.85	245.600	319.400	1.30
3	5.150	5.800	1.13	0.75	119.610	136.700	1.15
4	9.106	12.100*	1.33*	0.88	218.683	295.500	1.30*
Total	32.816	41.400	1.26	0.83	849.733	1082.700	1.28
Aug. 4, 1945 Pressure: Maximum 98 psi., Minimum 90 psi.							
1	7.380	7.600	1.04	0.68¢	235.730	241.500	1.03
2	8.000	8.300	1.04	0.68	248.240	256.100	1.03
3	6.500	6.500	1.00	0.66	138.140	138.300	1.00
4	12.470	12.900	1.03	0.68	242.620	248.400	1.02
Total	34.350	35.300	1.03	0.68	864.730	884.300	1.02
Aug. 21, 1945 Pressure: Maximum 95 psi., Minimum 90 psi.							
1	7.310	7.500	1.03	0.68¢			
2	8.450	8.500	1.01	0.67			
3	7.360	7.300	.99	0.65			
4	8.690	9.000	1.03	0.68			

* Pump No. 4 discharge restricted due to steam pump discharging into same 24-in. line.

the reduction in pressure it was possible to supply all demands without having to resort to the voluntary rationing which was necessary in 1944.

Table 4 illustrates how closely the two reservoirs act in unison under fairly heavy demand conditions. It will be noted that until 7:00 A.M. the water levels were within a few inches of being equal. As the full design conditions of usage have not yet been reached, it is necessary to keep the inlet valve to the South Side Reservoir from one-fourth to one-half open so that the flow to the two reservoirs will be more nearly equal.

From the data presented in the tables it is evident that attempts to reduce the operating pressure were successful. The fact that in the summer of 1945 no complaints of low pressure were received indicates that the customers were satisfied.

Table 5 shows the effect that lowering the pressure and operating the pumps more uniformly over the 24-hour period had on the pumping power cost. Electric power is purchased at a rate averaging about 0.66¢ per kwhr. In August 1944, before the larger feeder mains and reservoirs were placed in service, it cost 0.83¢ per 1,000 gal. to

pump water under the pressure necessary to supply the demands. In August 1945, with the mains and reservoirs in service, the cost dropped to 0.68¢ per 1,000 gal. Assuming that the same quantity of water was pumped in August 1945 as was pumped in August 1944, the saving in power cost would have been $1,297.10. The cash saving in power cost is, of course, important, but the reduction in operating pressur and the operation of pumping equip ment under more uniform condition are of greater importance. Thus it i felt that, while fulfilling a war demand the department has, by careful engi neering and planning, made permanen improvements to the water works whic will be beneficial for many years t come.

A Study of Corrosion Control With Sodium Hexametaphosphate

By Peter E. Pallo

Asst. San. Engr., Hackensack Water Co., New Milford, N.J.

Presented on Nov. 8, 1945, at the New Jersey Section Meeting, Atlantic City, N. J.

MODERN water works practice and sound engineering principles emphasize that the transmission and distribution systems transporting water be efficient and economical, and that there be no deterioration of either the potable or palatable quality of the commodity during the transportation process. Water works men, in attempting to conform with these principles and practices, are fully aware of the direct challenge that the internal corrosion of cast-iron and steel mains offers, and can readily appreciate that the proper protection of water mains is of vital and growing importance.

The industry has attempted to secure this protection against corrosion by the provision of constantly improved pipe linings, the use of nonmetallic pipe material and the adoption of corrective chemical treatment of the plant effluent.

During the past few years, corrective chemical treatment employing pyrophosphates, in conjunction with organic compounds, silicates and polyphosphates, has been the subject of much research. One of the polyphosphates used in this comparatively new approach to the problem of corrosion control has been sodium hexametaphosphate. The corrective or threshold treatment has been observed with keen interest by the water works fraternity, for considerable difference of opinion exists concerning the merits of the treatment.

A review of the literature dealing with the use of metaphosphate in corrosion control indicates that much excellent work has been done in studying the effect of two variables, i.e., pH and phosphate concentration, but that there has been relatively little investigation of the effect of a third and most important variable, the rate of flow. Rice (1) has consistently and insistently stated that "an investigation is incomplete which does not cover the influence of rate of flow on the degree of protection attained. . . ."

In its exhaustive survey of the subject of threshold treatment, the 1942 A.W.W.A. Committee on Water Conditioning to Inhibit Corrosion (2) arrived at two of several conclusions, which, together with the lack of information on the influence of rate of flow, stimulated the undertaking of the author's investigation. These conclusions were:

1. In ferrous metal piping systems, the use of metaphosphates will nearly always eliminate, or at least minimize, the outward manifestations of corrosion, particularly red water and tuberculation.

2. Conflicting evidence as yet forbids a definite statement as to whether metaphosphate does or does not prevent actual corrosion of ferrous metals, using the term corrosion in the sense of removal of metal from the surface. The members of the Committee are not in agreement on this question.

It is a well-recognized fact that the absence of such outward manifestations of corrosion as dissolved oxygen drop, iron pickup and increased loss of head does not preclude that corrosion is not taking place. It is further recognized that any chemical used in corrosion control must effectively form a protective film or coating at the metal-liquid boundary, whereby a material reduction in the loss of metal from the metal surface is achieved.

The author's investigation was therefore designed to determine the extent of corrosion with both threshold treated and untreated water as influenced by different rates of flow, and the degree of protection attained was measured in terms of the actual removal of metal from the metal surface, as well as by the outward manifestations of corrosion.

Investigation

The study was conducted upon as practical a basis as possible. Black steel pipe was selected as the metal to be used, for the reason that its resistance to corrosion in aggressive waters is exceedingly low, and the need for protection therefore correspondingly high.

The experimental installation was erected at the purification plant of the Hackensack Water Company at New Milford, N.J., and water for the investigation was furnished from this purified surface supply. The filter plant effluent exhibits a moderately aggressive tendency, as indicated by a maximum, minimum and average saturation index of − 1.6, − 0.8 and − 1.2, respectively, and was taken as it came with all seasonal variations in temperature, dissolved oxygen and both chemical and mineral content. An average analysis of the untreated influent water for the 13 months of the investigation is as follows:

		ppm.
pH	7.3	
Color		6
Turbidity		0
Free CO_2		4
Alkalinity (M.O.) ($CaCO_3$)		51
Soap Hardness ($CaCO_3$)		62
Total Iron		0.03
Total Solids		122
Magnesium		4.3
Calcium		24.6
Sulfates		29.2
Chlorides		11.0
Silica		4.2
Dissolved Oxygen		9.5

A phosphate dose of 2 ppm. was applied, for this dosage conformed more or less with existing practice on plant scale where effective corrosion inhibition has been reported.

The different rates of flow employed were 0.05, 0.27, 1.35, and 5.40 gpm., which are consonant with rates used in actual practice. As an indication of the type of flow prevailing at the start of the investigation, the Reynolds number for each flow was calculated to be:

Q—gpm.	Reynolds Number	Type of Flow
0.05	175	Laminar
0.27	828	Laminar
1.35	4,700	Turbulent
5.40	18,900	Turbulent

Installation

The flow diagram of the experimental installation (Fig. 1) may be briefly described in the following manner. A 55-gal. steel drum served as a phosphate solution reservoir from which the solution flowed by gravity to a 15-gal. constant level tank providing a Proportioneers pump with suction. The pump, in turn, discharged the phosphate solution into an untreated influent water line connected to a baffled transite header (or mixing cham-

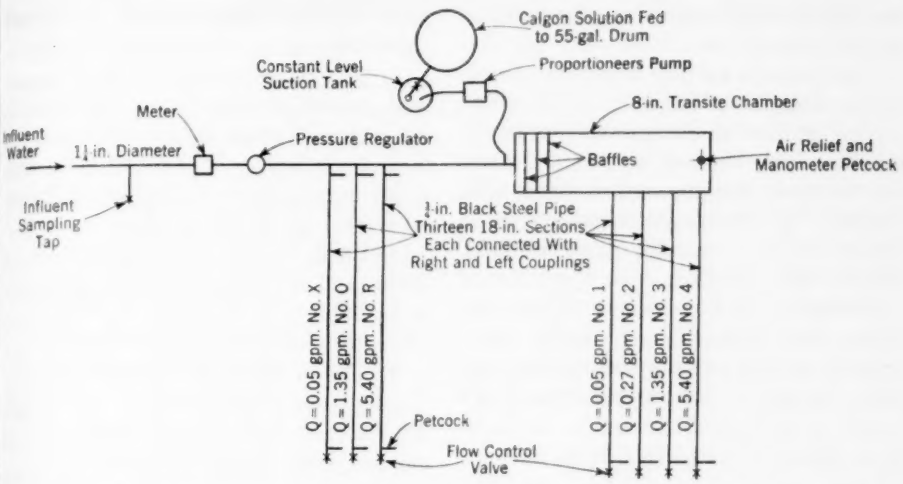

Calgon Solution Fed to 55-gal. Drum
Constant Level Suction Tank
Proportioneers Pump
8-in. Transite Chamber
Meter
Influent Water
1¼ in. Diameter
Pressure Regulator
Baffles
Air Relief and Manometer Petcock
Influent Sampling Tap
¾-in. Black Steel Pipe Thirteen 18-in. Sections Each Connected With Right and Left Couplings
Q = 0.05 gpm. No. X
Q = 1.35 gpm. No. O
Q = 5.40 gpm. No. R
Q = 0.05 gpm. No. 1
Q = 0.27 gpm. No. 2
Q = 1.35 gpm. No. 3
Q = 5.40 gpm. No. 4
Petcock
Flow Control Valve

FIG. 1. General Arrangement of Corrosion Control Installation—Hackensack Water Co., New Milford, N.J.

ber) from which the now-phosphate-treated water flowed through four 20-ft. lengths of ¾-in. diameter black steel pipe at different, but constant, rates. The effluent thence discharged to waste.

Two, and later three, 20-ft. lengths of black steel pipe were installed to carry untreated water at three of the same rates as did the phosphate treated water lines.

The interior of the steel drum was cleaned and painted with two coats of red lead and one coat of aluminum to eliminate corrosion effects within the phosphate solution reservoir.

The transite header or mixing chamber consisted of a 4-ft. length of 8-in., preleached transite pipe, baffled at the influent end to insure intimate mixing of the phosphate solution and influent water. Taps for four ¾-in. control pipes were made longitudinally along the side of the discharge end of the transite header, which was further provided with an air relief and sampling tap.

The ¾-in. black steel pipes were purchased in 20-ft. lengths in the open market, and were then carefully cut into thirteen 18-in. length sections per 20-ft. length, and threaded both left and right to facilitate installation and removal from the experimental system.

All 18-in. specimens were lightly wire-brushed to remove loose mill scale. They were then washed with naptha gas and alcohol to remove any adhering grease or oil. The outside of each specimen was cleaned and painted to prevent loss of iron due to atmospheric corrosion. When dried, the sections were given a final interior and exterior terry cloth rub, and the weight of each was determined to the nearest tenth of a gram on a laboratory scale. Observations were made and descriptions were recorded of the condition of the interior surface of each section.

Each line was made up with right- and left-hand couplings and, insofar as could be determined, the sections were drawn up so as to butt within the couplings. This was done to minimize

the effect of sudden enlargement upon the velocity of flow.

The quantity of flow was maintained by operating the flow control valves installed at the discharge end of each pipeline and, further, the total quantity of flow for the seven lines was checked by observations made on a meter installed on the main influent line for that purpose.

Petcocks were provided at the influent and effluent ends of the pipelines for the purpose of measuring head loss through a loss-of-head manifold installed midway between the influent and effluent ends of the pipelines.

General Procedure

Samples were collected from the untreated influent water line, the transite dosing chamber and the discharge of the three untreated and four treated water lines on the average of once every ten days.

The analyses made on each of the nine samples collected included the following determinations: temperature, color, pH, alkalinity, free CO_2, dissolved oxygen and total iron.

At the end of each service period, pipe sections removed from the installation were replaced with new pipe sections prepared in the same manner as outlined earlier in this report. Prior to removal and after replacement of the sections, loss-of-head measurements were obtained on each pipeline.

Upon removal from the system, the sections were stored until dry and examinations were then made and recorded of the interior condition of each section.

The following procedure for cleaning the removed sections was followed:

1. The sections were tapped along the longitudinal axis, thereby removing tubercles and scale formation which were collected and stored for future chemical and/or microscopic analysis.

2. The outside surface was cleaned with white naptha gas. The threads on each end were lightly wire-brushed and thoroughly bristle-brushed with white naptha gas to remove all lampwick and hardened graphite.

3. Each section was placed on a lathe and dry-reamed with a plastic rod. This was followed by five complete strokes with a wire brush.

4. The sections were removed from the lathe and cleaned in a water bath by plastic rod plunger action and flushed with pressure water.

5. Each section was then placed back on the lathe, dried inside and out with terry cloth, and vigorously bristle-brushed inside with white naptha gas.

6. The sections were then washed with alcohol, until there was no discoloration of the alcohol wash effluent, and allowed to drain and dry.

7. After a final interior and exterior terry cloth rub, the section was weighed to the nearest tenth of a gram on a laboratory scale.

The procedure as indicated above proved to be satisfactory for six of the seven pipe sections cleaned. The seventh specimen represented that line carrying treated water at the 5.40 gpm. rate, and presented an interior surface coating which was extremely difficult to remove, in that the coating was tough, well knit and firmly adherent. As a first step in cleaning operations, it was found necessary to wire brush thoroughly the specimen in order to remove satisfactorily the corrosion products.

Following the final weighing operation, each specimen was carefully wrapped and stored for further examination at some future date.

Results of Experimental Work

The presentation of the results of the experimental work will be divided into two sections; the first deals with the influence of rate of flow upon the pipelines carrying threshold treated water only, and the second deals with a comparison of those pipelines carrying threshold treated and untreated water at comparable rates of flow.

I. Pipelines Carrying Threshold Treated Water Only

Rate of Corrosion: Corrosion-time diagrams reveal the extent to which protective coatings formed by the products of corrosion or those induced by chemical treatment affect the rate of corrosion. Such diagrams for the threshold treated lines are presented in Fig. 2. From the figures it will be

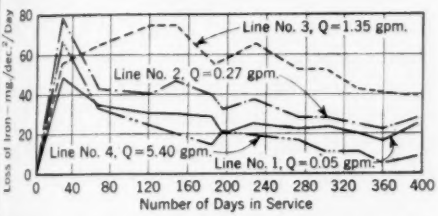


FIG. 2. Rate of Loss of Iron in Threshold Treated Lines

noted that corrosion rates increased with increasing rates of flow to some indicated probable critical rate, after which, further increase in the rate of flow decreased the corrosion rate to a low value. Average daily rates of corrosion for the duration of the 393 days of the investigation are as follows:

	Loss of Iron—*mg./dec.²/day*		
Q—*gpm.*	Maximum	Minimum	Average
0.05	48.2	17.0	27.3
0.27	79.2	22.5	37.6
1.35	74.9	39.6	56.0
5.40	66.7	5.8	21.2

The corrosion-time diagrams further indicate that threshold treated water did not prevent the actual removal of ferrous metal from the wall of the pipe at any of the rates of flow employed in this study, but they do show a marked reduction in the removal of metal beyond the indicated critical rate of flow. The results, therefore, substantiate Rice's contention that "if good results are to be secured, the flow must be rapid enough to insure turbulence so that intimate contact of the metaphosphate with the surface will be assured" (3).

Other investigators employing distilled and natural waters as the corroding medium, however, noticed that velocity had a marked effect upon the rate of corrosion. Heyn and Bauer (4) and Friend (5) found that increasing the velocity of relative motion increased the corrosion rate until a maximum rate was reached, and that further increase of velocity caused the rate to decrease. Speller and Kendall (6), under radically different conditions of experimentation, found that the corrosion rate of steel pipe with Pittsburgh tap water flowing through it increased with increasing velocity, with no indication of a decrease in corrosion over the entire range covered by either of the previous investigators. Russell, Chappell and White (7) showed that freshly cleaned iron gave results similar to those obtained by Friend, i.e., the corrosion rate first rose with increasing water velocities, and then, when the velocity had become high enough to supply oxygen in excess to the whole surface, fell again. Roetheli and Brown (8) concluded from results of experimentation that "A maximum rate of corrosion is obtained as velocity is increased because of the combined effect of two opposing

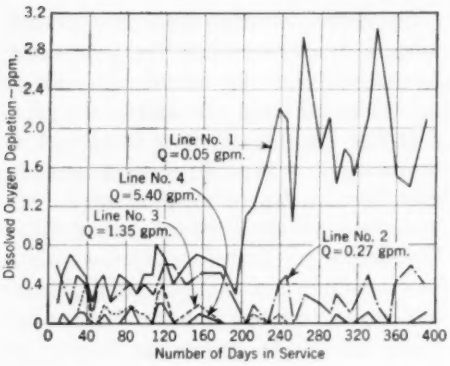

Dissolved Oxygen Depletion – ppm.
Number of Days in Service
Line No. 1 Q=0.05 gpm.
Line No. 4 Q=5.40 gpm.
Line No. 3 Q=1.35 gpm.
Line No. 2 Q=0.27 gpm.

FIG. 3. Dissolved Oxygen Depletion in Threshold Treated Lines

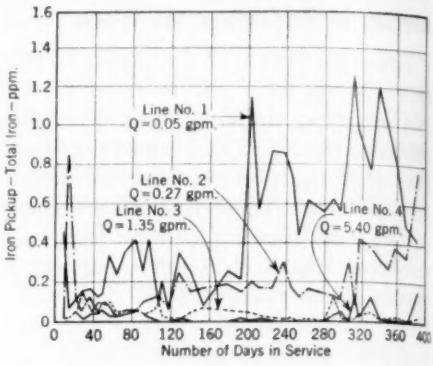


FIG. 4. Iron Pickup in Threshold Treated Lines

tendencies: (a) the decreased resistance to diffusion of oxygen due to a reduction of liquid film thickness and (b) the increased resistance of the corrosion product at the speed at which ferric hydroxide commences to form."

Oxygen Depletion: Maximum oxygen depletion values were found at low rates of flow, decreasing to a minimum with increasing rates of flow (Fig. 3). The maximum, minimum and average oxygen depletion results for the duration of the investigation were:

	Oxygen Depletion—*ppm.*		
Q—*gpm.*	Maximum	Minimum	Average
0.05	3.0	0.2	1.12
0.27	0.6	0	0.32
1.35	0.4	0	0.07
5.40	0.2	0	0.03

This behavior is to be expected, since, initially, the time of contact between the metal surface and a given quantity of water decreases as the rate of flow increases, and this variation in the rate of flow influences the thickness of the film liquid and the type of corrosion product formed. Roetheli and Brown (8) have shown the corrosion product formed at low velocities to be a granular, magnetic oxide of iron, which is not very resistant to the diffusion of oxygen. They further found the product formed at high velocities to be a protective, gelatinous ferric hydroxide which greatly retards the diffusion of oxygen.

Iron Pickup: Maximum iron concentrations were found in the effluents of those pipelines carrying the low-rate flows, and the iron pickup decreased as the rate of flow increased (Fig. 4). The maximum, minimum and average iron pickup values were found to be:

	Iron Pickup in Effluent—*ppm.*		
Q—*gpm.*	Maximum	Minimum	Average
0.05	1.27	0.05	0.51
0.27	0.76	0.02	0.20
1.35	0.16	0.0	0.04
5.40	0.07	0.0	0.01

Products of corrosion formed in conjunction with threshold treatment at low rates of flow were found to be more easily disturbed and the discoloration of the effluent to persist for longer periods of time than was evidenced in the untreated, low rate of flow lines. Other investigators (9) have noticed this effect.

Loss of Head and Tuberculation. Resistance to flow caused by adherent

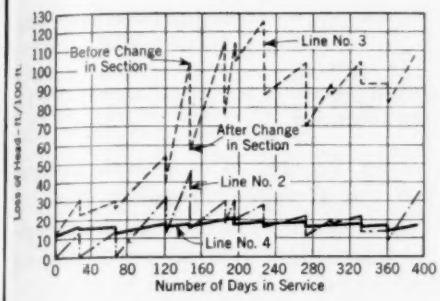

Loss of Head - ft./100 ft.
Before Change in Section
After Change in Section
Line No. 3
Line No. 2
Line No. 4
Number of Days in Service

FIG. 5. Comparison of Loss of Head for a Selected Q = 4.0 gpm.

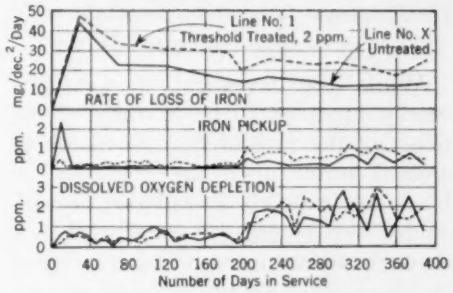


FIG. 6. Comparison of Experimental Results on Threshold Treated and Untreated Lines for Q = 0.05 gpm.

products of corrosion was found to increase with increasing rates of flow to an indicated critical rate and then to decrease with further increase in the rate of flow.

To illustrate by comparison the degree to which tuberculation progressed in three of the treated pipelines, head losses for a selected Q of 4.0 gpm. were calculated on the basis of the actual head loss measured in each line before and after removal of pipe sections. Head losses for the 0.05-gpm. line could not be measured with a 1.25 sp.gr. liquid, and the initial head prevented the use of a water column.

The calculated results, presented in graphic form in Fig 5, show the head losses to be:

	Loss of Head—*ft. per 100 ft.*		
Q Actual	Maximum	Minimum	Average
0.27	32.9	—	17.9
1.35	126.0	11.4	76.1
5.40	20.9	11.5	16.8

Examination of the pipe sections carrying 0.05 gpm., which were removed after periods of service, showed the effective cross-sectional area to be but slightly decreased and the products of corrosion to consist mainly of strips of flat, reddish-brown scale and sparse reddish-brown tuberculation to $\frac{1}{16}$ in. high, both in definite longitudinal streaks, probably due to longitudinal breaking of original mill scale in the manufacture of pipe.

A slight decrease in the cross-sectional area of the pipe sections carrying 0.27 gpm. over the 0.05-gpm. sections was noted. Scale formation was not as apparent as in the 0.05 gpm. sections, there being a decided tendency to tuberculate in longitudinal streaks. Red tubercular deposits to $\frac{1}{16}$ in. high were found to be more thick and dense than those in Line No. 1.

Line No. 3, which carried 1.35 gpm., showed the greatest loss of head, indicating serious tuberculation. The decrease in the cross-sectional area of the pipe sections was found to be severe, in that the formation of tubercles became thicker, bulkier and higher as the investigation progressed until there was but a $\frac{3}{8}$-in. diameter channel apparent through those sections being progressively removed.

The 5.40-gpm. pipelines showed only a slight decrease in cross-sectional area. The products of corrosion were found to be a hard, strongly adherent coating from film thickness to less than $\frac{1}{32}$ in. high with sparse tubercle formation to $\frac{1}{32}$ in. high.

II. Pipelines Carrying Threshold Treated and Untreated Water

While the investigation was primarily intended to be a study of the effect of the rate of flow of threshold treated water upon the corrosion of black steel pipe, the installation also included two lengths of black steel pipe through which untreated water flowed at two rates comparable to those employed in the threshold treated lines, namely 0.05 and 1.35 gpm. As the investigation progressed, it became evident from the results secured that it would be of utmost interest and importance to include another pipeline carrying untreated water at 5.40 gpm. This line was installed 273 days after the start of the original investigation and will be discussed in detail later in this report.

Rate of Flow 0.05 gpm.

Rate of Corrosion: The corrosion-time diagram, Fig. 6, shows the threshold treated water to be more aggressive than the untreated water, in that the loss of iron for the threshold treated pipeline proceeded at an average daily rate 50 per cent greater than that found in the untreated pipeline. Daily rates of iron loss for the duration of the investigation were:

	Loss of Iron—*mg./dec.²/day*		
Q—gpm.	Maximum	Minimum	Average
0.05 Treated	48.2	17.0	27.3
0.05 Untreated	44.8	11.4	18.1

Oxygen Depletion: Oxygen depletion results for the threshold treated pipeline showed an average increase of 0.1 ppm. over the pipeline carrying water receiving no treatment. Oxygen depletion values were found to be:

	Oxygen Depletion—*ppm.*		
Q—gpm.	Maximum	Minimum	Average
0.05 Treated	3.0	0.2	1.1
0.05 Untreated	2.9	0.1	1.0

Iron Pickup: The results indicate that the average increase in the iron content of the effluent from the threshold treated line to be 63 per cent above that found in the effluent of the pipeline carrying water receiving no treatment. Iron pickup concentrations for the investigation were:

	Iron Pickup—*ppm.*		
Q—gpm.	Maximum	Minimum	Average
0.05 Treated	1.27	0.05	0.51
0.05 Untreated	2.47	0.0	0.30

Loss of Head and Tuberculation: As mentioned earlier in this report, loss-of-head measurements could not be obtained at this rate of flow, and inspection of the pipe sections showed both the treated and untreated pipelines to be but slightly decreased in effective cross-sectional area. The products of corrosion consisted mainly of strips of reddish-brown scale and sparse tuberculation to $\frac{1}{16}$ in. high, both in definite longitudinal streaks. The interesting observation made of the tubercle formation was found to be in the difference in appearance of the tuberculation. The tubercles formed in the threshold treated pipe appeared to be flatter and slightly bulkier than those found in the line receiving no treatment.

Rate of Flow 1.35 gpm.

Rate of Corrosion: The corrosion-time diagram, Fig. 7, indicates the threshold treated water to be more aggressive than the untreated water for this probable critical rate of flow

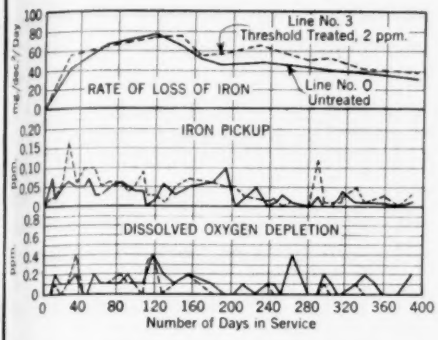


FIG. 7. Comparison of Experimental Results on Threshold Treated and Untreated Lines for Q = 1.35 gpm.

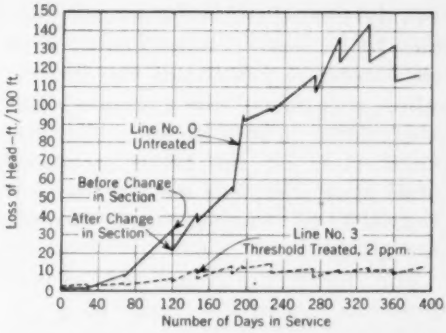


FIG. 8. Comparison of Loss of Head Between Threshold Treated and Untreated Lines for Q = 1.35 gpm.

Loss of iron for the threshold treated pipeline proceeded at an average daily rate 15 per cent higher than that found in the untreated pipeline. Daily rates of iron loss for the duration of the investigation were:

	Loss of Iron—*mg./dec.²/day*		
Q—gpm.	Maximum	Minimum	Average
1.35 Treated	74.9	39.6	56.1
1.35 Untreated	77.1	32.3	48.8

Oxygen Depletion: Oxygen depletion values for the threshold treated line showed an average decrease of 0.03 ppm. below that found in the effluent of the untreated pipeline. Oxygen depletion values for the duration of the investigation were found to be:

	Oxygen Depletion—*ppm.*		
Q—gpm.	Maximum	Minimum	Average
1.35 Treated	0.4	0	0.07
1.35 Untreated	0.4	0	0.10

Iron Pickup Concentrations: The results indicate the average increase in the iron content in the effluent of the threshold treated line to be 0.01 ppm. greater than that found in the effluent of the untreated water line. Iron pickup concentrations for the duration of the investigation were:

	Iron Pickup—*ppm.*		
Q—gpm.	Maximum	Minimum	Average
1.35 Treated	0.16	0	0.04
1.35 Untreated	0.10	0	0.03

Loss of Head and Tuberculation: Loss of head measurements, presented graphically in Fig. 8, show the average loss of head for the untreated pipeline to be 757 per cent higher than the loss of head measured in the threshold treated pipeline. Maximum, minimum and average losses of head were:

	Loss of Head—*ft./100 ft.*		
Q—gpm.	Maximum	Minimum	Average
1.35 Treated	14.4	1.3	8.7
1.35 Untreated	143.8	0.6	74.6

The results preclude any argument regarding the ability of threshold treatment to reduce the rate of tuberculation, but, to judge the economic significance properly, the increased loss of metal must not be overlooked.

Inspection of the pipe sections removed after periods of service revealed

both the treated and the untreated pipelines to be heavily tuberculated, with one exception, namely, as the investigation progressed, the untreated line tuberculated to such an extent as visibly to close off the entire cross-sectional area, while the treated line still contained an effective open channel throughout.

The tuberculation formed in the threshold treated line appeared to be much flatter and bulkier than that found in the untreated line. The term "flatter" may be further described as indicating a rounded truncated cone, which in mass gave the impression of bulk when compared to the cone-shaped tubercles formed in the untreated water line.

Rate of Flow 5.40 gpm.

Because of the nature of the results secured with the threshold treated lines, and because evidence was accumulating to indicate that at low rates of flow phosphate treatment resulted in a greater loss of iron than that measured in the untreated lines, a seventh black steel pipeline carrying untreated water at a 5.40-gpm. rate was installed 273 days after the start of the original investigation.

No exact comparison may be made between the treated and untreated lines inasmuch as both lines were not subjected simultaneously to the effects of the varying seasonal characteristics of the untreated influent water. Nevertheless, the data obtained warrant inclusion in this report.

The corrosion-time and loss-of-head diagrams, presented in Fig. 9, show the average daily loss of iron in the threshold treated line for 393 days of service to be slightly higher by 2.4 per cent than the loss in the untreated line which was in service for 435 days.

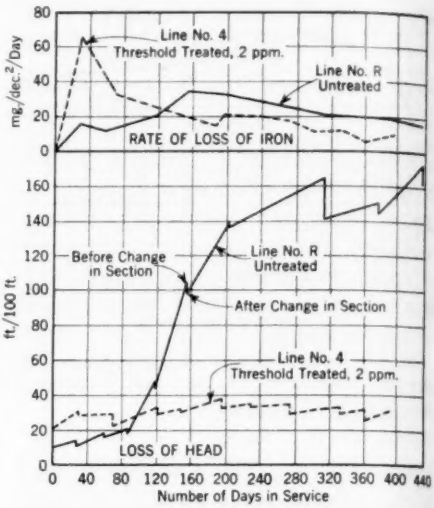


FIG. 9. Comparisons of Rates of Loss of Iron and Loss of Head Between Threshold Treated and Untreated Lines for Q = 5.40 gpm.

The daily rates of iron loss were as follows:

Days in Service	Q—*gpm.*	Loss of Iron—*mg./dec.²/day* Maximum	Minimum	Average
393	5.40 Treated	66.7	5.8	21.2
435	5.40 Untreated	34.2	11.9	20.7

The loss of head developed in the untreated line proceeded at an average rate of 163 per cent above that found in the threshold treated line, and the maximum, minimum and average head losses were:

Days in Service	Q—*gpm.*	Loss of Head—*ft./100 ft.* Maximum	Minimum	Average
393	5.40 Treated	38.1	21.0	30.6
435	5.40 Untreated	173.0	10.5	80.7

Examination of the interior of the removed 18-in. length sections during the 435 days of service of the untreated line revealed a progressively dense tuberculation to ¼ in. high, while the

treated line after 393 days of service showed a yellowish-brown coating from film thickness to $\frac{1}{32}$ in. high with a slight amount of scattered tuberculation. As in the case of the 1.35-gpm. flow, the threshold treatment displayed the same characteristic ability to maintain an open pipe by materially decreasing the rate of tuberculation.

Summary of Results

This investigation is but one of the many further studies necessary for a more thorough understanding of the corrosion inhibiting effect of the chemical, sodium hexametaphosphate, and is offered as a contribution to the ever increasing accumulation of data from which conclusions may finally be derived.

There is, however, one final conclusion which may be drawn from this investigation, and that conclusion is: To be of practical value, any corrosion control investigation must include the influence of rate of flow. The water works engineer can readily appreciate this, for distribution systems consist of varied diameter mains, grid-iron and dead ends.

The summary will be divided into two sections, the first dealing with the threshold treated lines only, and the second with both the treated and untreated lines.

I. Threshold Treated Lines

1. The corrosion inhibiting effect of threshold treatment is materially affected by the type of corrosion product formed at the various rates of flow.

2. Threshold treatment does not prevent the actual removal of metal from the metal surface at any of the rates of flow employed in this study.

3. The rate of corrosion (removal of metal from the metal surface) was found to increase with increasing rates of flow to some critical rate of flow, after which the corrosion rate decreased to a low value.

4. The rate of tuberculation was found to increase with increasing rates of flow to some critical rate of flow, after which the rate of formation of the friction causing components was materially reduced.

II. Threshold Treated and Untreated Lines

1. Under conditions of low rates of flow and up to and including some critical rate of flow, the rate of corrosion was found to be higher in the threshold treated lines than in those lines receiving no treatment.

2. Threshold treated lines showed a marked inhibiting effect in the rate of tuberculation over those lines receiving no treatment.

3. Under conditions of low rates of flow, the products of corrosion formed in conjunction with threshold treatment appeared to be more loosely adherent to the pipe wall than those products formed with water receiving no treatment.

Acknowledgments

Among those who have professed a keen interest in the progress of this study, grateful acknowledgment is due particularly to: the management of the Hackensack Water Company, Weehawken, N.J., who graciously provided the room and the water for the experimental study, as well as the facilities of both the analytical laboratory and machine shop and the Hall Laboratories, Inc., Pittsburgh, Pa., for supplying the Calgon used for the investigation. Appreciation is extended to Major Rolf Eliassen, U.S. Army, Fort Douglas, Utah; Edmond H.

Thwaits, Research Engineer, American Iron and Steel Institute, New York City; and Owen Rice, Research Engineer, Hall Laboratories, Inc., Pittsburgh, Pa., who have so generously contributed of their time, guidance and criticism.

References

1. Rice, Owen. *Private Communication.*
2. *Report of A.W.W.A. Committee on Water Conditioning Methods to Inhibit Corrosion.* Jour. A.W.W.A., **34**: 1807 (1942).
3. Rice, Owen. Plant Results With Threshold Treatment. W.W. Eng., **95**: 7: 368 (1942).
4. Heyn & Bauer. Mitt. Kgl. Material prufungsamt (Ger.), **28**: 62 (1910).
5. Friend, J. A. N. Corrosion of Iron. Carnegie Scholarship Memoirs, **XI**: 129, Iron & Steel Inst., London (1922).
6. Speller, F. N. & Kendall, V. V. Ind. Eng. Chem., **15**: 134 (1923).
7. Russell, R. P., Chappell, E. L. & White, A. Effect of Velocity on Corrosion of Steel Under Water. Ind. Eng. Chem., **19**: 65 (1927).
8. Roethli, B. E. & Brown, R. H. Corrosion Rates of Steel and Composition of Corrosion Products Formed in Oxygenated Water As Affected by Velocity. Ind. Eng. Chem., **23**: 1010 (1931).
9. Stockwell, H. P., Jr. Application of Metaphosphate to Ferrous Metal Piping Systems. Jour. A.W.W.A., **34**: 1812 (1942).

This paper presents the results obtained in a research undertaken by the author as a graduate thesis submitted to the Graduate Division, College of Engineering, New York University, New York City.

Water Quality and Pollution Control in Western Pennsylvania

By C. H. Young

Dist. Engr., State Dept. of Health, Meadville, Pa.

Presented on Sept. 14, 1945, at the Western Pennsylvania Section Meeting, Pittsburgh, Pa.

PROBLEMS of raw water quality, pollution and pollution control are of vital interest to the water works operator and the public alike. This is especially true in the more densely populated parts of the country, where the surface stream serves as the principal source of public water supply. Western Pennsylvania is one of the densely populated parts of the country, having a population exceeding that of 37 of the 48 states. Some areas in western Pennsylvania present a complicated pollution problem, involving municipal sewage, acid mine drainage and a variety of industrial wastes.

Western Pennsylvania is considered to comprise approximately the 22 counties that drain either to Lake Erie or the Ohio River. Figure 1 and Table 1 have been prepared to show the drainage basins, their size, population, population densities and State Health Department Engineering Districts. It will be noted from Table 1 that the population density on the western Pennsylvania drainage basins substantially exceeds that of the United States or of the entire Ohio River basin. The Erie basin has the highest and the Beaver basin the second highest population density, whereas the Allegheny basin has the lowest population density.

About 80 per cent of the 4,350,000 persons residing on the Ohio drainage basin upstream from the Pennsylvania-Ohio State line live in Pennsylvania. It is worthy of noting that of the 3,500,000 persons residing in these counties about 2,400,000 are served by public water supplies, the source of which is the surface streams of the area. Municipal water supplies are taken from the Allegheny, Monongahela, Beaver and Ohio rivers, in that order of importance, according to the population served. The Ohio River in Pennsylvania serves as the source of only one public water supply.

TABLE 1

Western Pennsylvania Drainage Basins and Population Data

Drainage Basin	Basin Area, *sq. mi.*	Drainage Basin Population	Pennsylvania Population on Drainage Basin	Basin Population Density per sq. mi.
Erie	512	152,000	152,000	296
Beaver	3,145	730,000	310,000	232
Allegheny	11,730	1,235,000	1,090,000	105
Monongahela	7,380	1,265,000	900,000	171
Ohio River at State Line	22,117	4,350,000	3,420,000	196

Population density of U.S.: 39 per sq.mi.

Population density on entire Ohio River Basin: 92 per sq.mi.

The Pennsylvania State Health Department maintains two District Engineering offices in western Pennsylvania: District "D" comprising the seven counties in southwestern Pennsylvania and District "C" the twelve

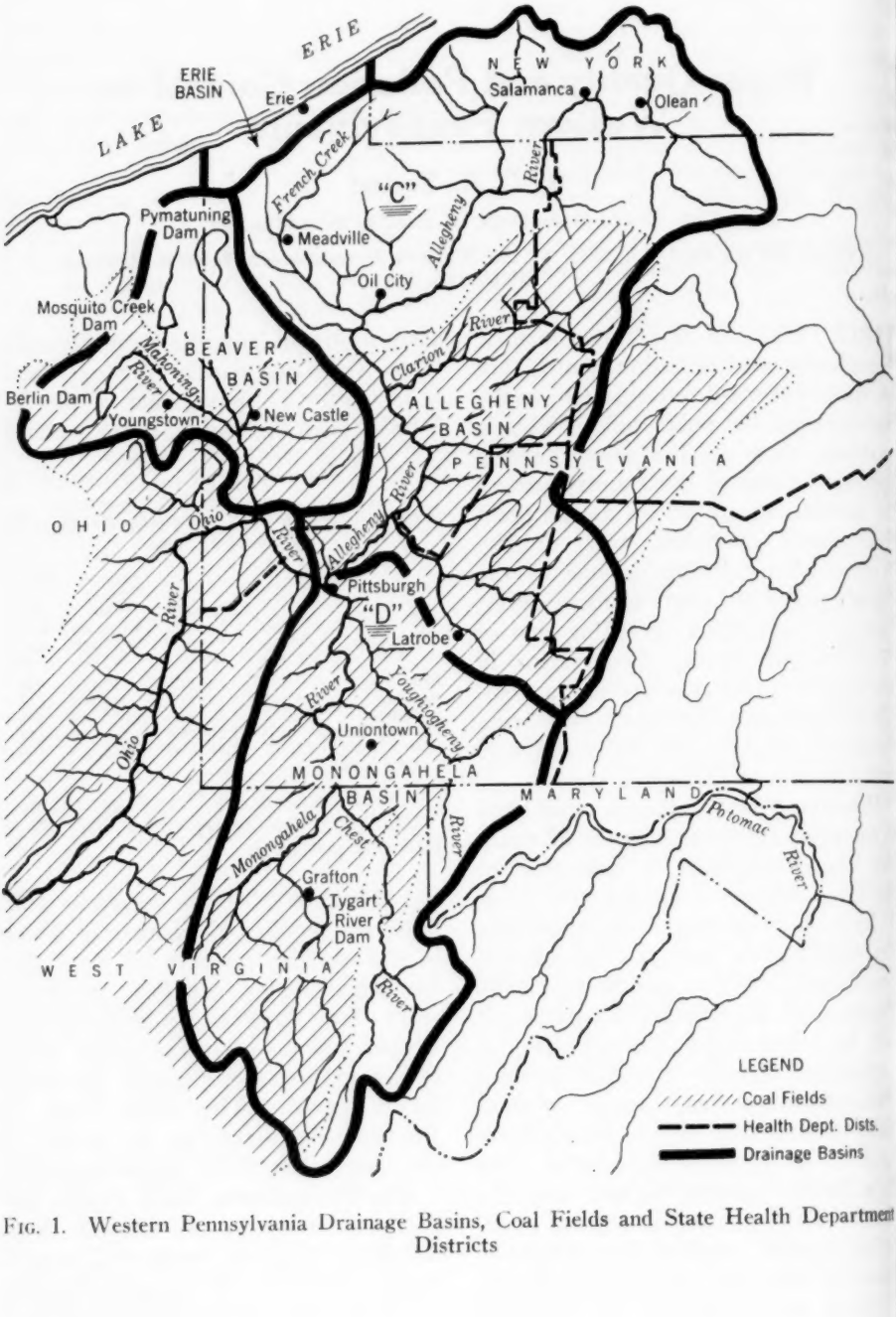


FIG. 1. Western Pennsylvania Drainage Basins, Coal Fields and State Health Department Districts

counties in northwestern Pennsylvania (Fig. 1).

From the industrial standpoint, coal mining and steel production are the principal industries of the area. Coal mining predominates in southwestern Pennsylvania. From Fig. 1 it will be seen that the northern half has little or no coal. There is a wide variety of industries located in the northwestern Pennsylvania district, including mining, chemical plants, milk processing and manufacturing, oil production and refining, metal works, distilleries, paper, steel and allied plants, tanneries, etc.

In order to discuss raw water quality, pollution and pollution control, it is advisable to consider the effects of the more important pollutants on the streams that serve as sources of public water supply. It should further be understood that the most important use of any stream is as a source of public water supply. Sewage pollution has a most adverse effect on raw water quality because of the danger from disease-producing bacteria and the limiting ability of water treatment plants to produce a safe water supply from a polluted source. One authority has indicated that a limiting raw water bacterial loading for a modernly equipped water filtration plant, including pre- and post-chlorination, should not exceed 20,000 coliform bacteria per 100 ml.

Certain industrial wastes likewise have adverse effects on raw water quality, chiefly because of their ability to produce taste and odors that are difficult and costly to remove, if, in the more difficult cases, complete removal can be secured. Wastes of this type are the so-called phenolic wastes from byproduct coke plants, tar compounds from chemical plants, waste waters from synthetic rubber and wood distillation plants, certain oily waste waters and organic wastes from tanneries, paper mills and the like. Organic wastes frequently have high and sometimes variable chlorine demands, and if present in appreciable amounts cause coagulation difficulties. Other industrial wastes have adverse effects on water quality by increasing the sulfate content or by producing fluctuations in pH, alkalinity, hardness, iron and/or manganese content, thus complicating the treatability of these supplies. The major wastes under this latter classification are the spent pickle liquors from the steel and allied industries.

Mine drainage also is detrimental to water quality. Mine drainage in western Pennsylvania generally is acid and the discharge of large amounts of mine drainage can and is affecting many of the streams in the mining areas to the extent that major streams are acid throughout almost the whole year. Mine drainage also contains impurities, such as hardening constituents, iron, aluminum and manganese, which can produce water treatment difficulties. Mine drainage, if uncontrolled, can affect a stream to the point where it will no longer be suitable as a source of public water supply and can further so affect the other uses of the stream as to make it a liability, instead of a valuable regional asset. Figure 2 shows the annual alkalinity of the Allegheny River at Aspinwall from 1909–44, and indicates the effect of acid mine drainage over the years on the alkalinity of this stream.

Lake Erie Basin

The Lake Erie basin is the smallest basin in western Pennsylvania, yet it has the highest population density.

Lake Erie serves as the source of one public water supply in Pennsylvania —the city of Erie. All municipal sewage discharged to this drainage basin is treated. There are four sewage plants of complete treatment and two plants of partial treatment, including

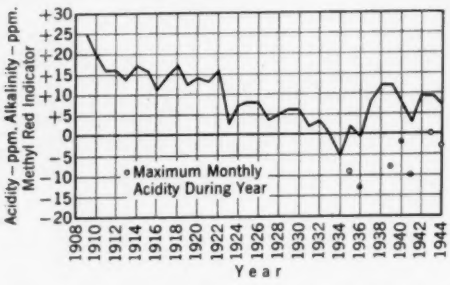


FIG. 2. Annual Alkalinity of Allegheny River at Aspinwall, Pa.—1909–1944

the Erie plant where the settled sewage is chlorinated during the summer. A number of industries treat their waste waters on this drainage basin. Further improvement is required in connection with a limited number of industries discharging waste waters. There is no mining on this basin.

Beaver River Basin

The Beaver River basin has a drainage area of 3,140 square miles and has the highest population density of the western Pennsylvania drainage basins tributary to the Ohio River. There are major pollution problems on this basin which are complicated further by virtue of the basin's being located in two states. The Mahoning and Shenango rivers each have drainage areas of approximately 1,100 square miles and join at New Castle, Pa., to form the Beaver River. Most of the Mahoning River drainage basin lies in Ohio, with Youngstown, Warren, Girard and Niles as the principal municipalities. The more important Pennsylvania municipalities on the Beaver River basin are New Castle, Sharon, Butler and Beaver Falls. The principal industrial development is steel and related manufacturing. There are four byproduct coke plants, all located in Ohio. Coal mining is limited and is confined to Beaver, Butler, Lawrence and a part of Mercer counties. The Shenango and Beaver rivers serve as the sources of public water supplies for approximately 150,000 persons; their tributaries serve as the sources of water supply for a number of municipalities. In addition, the major streams are used for cooling water by steel mills and other industrial establishments. Recreation on certain of the tributaries is becoming increasingly important.

The state of Pennsylvania constructed in 1933 the Pymatuning Dam near the head waters of the Shenango River to store flood waters and release the impounded water during low river flows as a means of improving stream sanitation and providing industrial cooling water. This dam was intended to increase low flows at Sharon from a record low of 8 cfs. to approximately 200 cfs. Similar reservoirs have been constructed on the Mahoning and a tributary in Ohio. Milton Dam was constructed some years ago on the Mahoning River to increase low flows for the steel mills at Youngstown, and during the past several years the federal government has constructed the Berlin and Mosquito Creek reservoirs as multiple-purpose, flood control and flow augmentation projects. These reservoirs, under present operations, are expected to maintain mean monthly river flows at Youngstown during the high temperature period from 300 to possibly 500 cfs.

Pennsylvania for a number of years has been carrying on a pollution control program on the watershed of the Beaver River and, as a result, every Pennsylvania municipality is operating a sewage treatment works. There is a total of 28 operating sewage treatment plants, 11 of which are plants of complete treatment. New Castle, Ellwood City and Mars have had plans prepared and approved to modernize and step up the degree of sewage treatment, have programs to finance the improvements, and are now doing certain work toward that objective. Evans City, Harmony and Greenville have employed engineers to prepare plans for secondary treatment. Grove City has employed engineers to improve and enlarge an existing plant of complete treatment.

Figure 3 is a profile of the Beaver River and its tributaries showing the location of the various municipalities, their population and size of drainage areas at the point of sewage discharge and the gradient of the receiving stream.

TABLE 2

Summary of Shenango River Sanitary Survey—Effect of Flow Augmentation on Available Oxygen—Upper Zone

Year and Station	Distance Below Dam, *mi.*	Temperature °C.	D.O., *ppm.*	Saturation, %	5-day B.O.D., *ppm.*	Mean River Discharge at Sharon, *cfs.*	Mean Pymatuning Dam Release, *cfs.*	Oxygen Balance at Sharpsville, *ppm.*	Oxygen Available,* *lb.*	Number of Determinations
1932 (1)										
Jamestown	1.5	19.5	6.72	73.2	1.49					
Greenville (2)	6.5	19.9	7.35	79.6	0.88					
Clarksville	27.0	20.7	7.73	83.8	1.09					
Sharpsville	33.0	21.6	8.30	91.5	0.85	47	0	7.45	1,030	11
1937										
Jamestown	1.5	22.7	6.55	75.0	2.95					
Greenville (2)	6.5	22.6	6.60	82.9	3.13					
Clarksville	27.0	23.3	7.66	88.7	4.33					
Sharpsville	33.0	24.1	8.25	96.7	3.66	343	218	4.59	2,070	4
1938										
Jamestown	1.5	24.6	7.15	84.8	3.20					
Greenville (2)	6.5	23.7	7.37	86.1	3.11					
Clarksville	27.0	24.7	7.75	92.4	3.27					
Sharpsville	33.0	26.5	8.55	105.2	3.67	202	102	4.88	1,540	4

(1) Before dam constructed.
(2) Two miles above.
* To maintain 3.5 ppm. residual D.O.

All important industries in Pennsylvania on the watershed treat either partially or completely their industrial wastes. There are a number of interesting waste treatment plants covering a fairly wide range of industries.

Studies are being made to decide whether a modification of the operation of the Pymatuning Reservoir can be made to fit better into the waste treat-

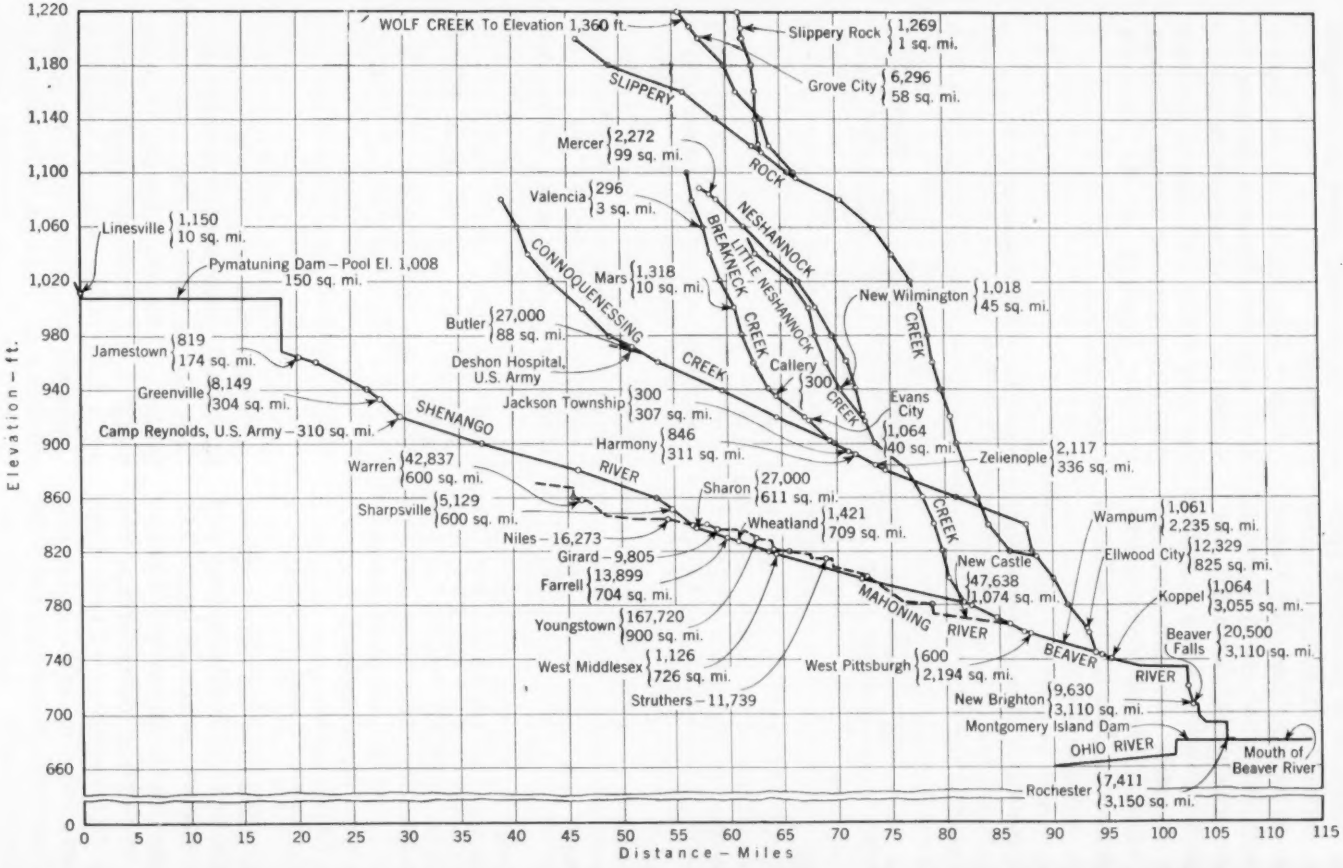

WOLF CREEK To Elevation 1,360 ft.
Slippery Rock 1,269 / 1 sq. mi.
Grove City 6,296 / 58 sq. mi.
SLIPPERY ROCK
Mercer 2,272 / 99 sq. mi.
Valencia 296 / 3 sq. mi.
NESHANNOCK
BREAKNECK CREEK
LITTLE NESHANNOCK CREEK
Linesville 1,150 / 10 sq. mi.
Pymatuning Dam – Pool El. 1,008 / 150 sq. mi.
CONNOQUENESSING
Mars 1,318 / 10 sq. mi.
New Wilmington 1,018 / 45 sq. mi.
Butler 27,000 / 88 sq. mi.
Jamestown 819 / 174 sq. mi.
Deshon Hospital, U.S. Army
CREEK
Callery 300
Greenville 8,149 / 304 sq. mi.
Jackson Township 300 / 307 sq. mi.
Evans City 1,064 / 40 sq. mi.
Camp Reynolds, U.S. Army – 310 sq. mi.
SHENANGO
Harmony 846 / 311 sq. mi.
Zelienople 2,117 / 336 sq. mi.
Warren 42,837 / 600 sq. mi.
RIVER
Sharon 27,000 / 611 sq. mi.
Wampum 1,061 / 2,235 sq. mi.
Sharpsville 5,129 / 600 sq. mi.
Wheatland 1,421 / 709 sq. mi.
Niles – 16,273
Girard – 9,805
Ellwood City 12,329 / 825 sq. mi.
New Castle 47,638 / 1,074 sq. mi.
Farrell 13,899 / 704 sq. mi.
MAHONING RIVER
Koppel 1,064 / 3,055 sq. mi.
Youngstown 167,720 / 900 sq. mi.
Beaver Falls 20,500 / 3,110 sq. mi.
West Middlesex 1,126 / 726 sq. mi.
West Pittsburgh 600 / 2,194 sq. mi.
BEAVER RIVER
Struthers – 11,739
New Brighton 9,630 / 3,110 sq. mi.
Montgomery Island Dam
OHIO RIVER
Mouth of Beaver River
Rochester 7,411 / 3,150 sq. mi.
Elevation – ft.
Distance – Miles

FIG. 3. Profile of Beaver River and Tributaries (Mahoning River to Warren, Ohio, Only)—Showing Populations (1940 Census) and Drainage Areas (Data From U.S.G.S. Topographical Sheets, Dept. of Forests and Waters, Hydrology Div.; and U.S. Engineers)

ment and water supply program on the main rivers.

The Shenango River between the Pymatuning Dam and the Sharon water works intake, with the exception of the zone immediately below Greenville, is a relatively clean stream. Table 2 shows the effect of flow augmentation from the Pymatuning Reservoir on the available oxygen on this part of the river, since it is usually considered that the assimilating capacity of a stream for organic wastes is increased approximately in relation to the increased river flows. The table gives river results before the dam was constructed and for the 2 years after the dam was placed in full operation. It will be noted that with flow augmentation the discharge at Sharpsville increased approximately five times over the unregulated flow period, yet the available dissolved oxygen increased less than twice. This, because the dissolved organic impurities from the swampy area of the dam impart an appreciable B.O.D. and otherwise affect the river water.

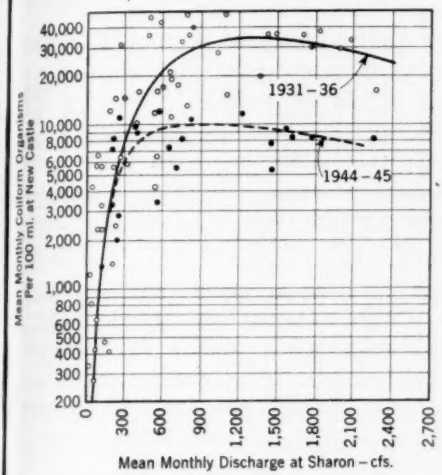


FIG. 4. Effect of Sewage Treatment Program on Coliform Densities of Shenango River

The Shenango River below Farrell through to the confluence of the Shenango and the Mahoning rivers needs further correction. Figure 4 shows the improvement in coliform density of the Shenango River water at the New Castle water works intake through the sewage treatment program. Further improvement calls for the completion of a program requiring the large mills to collect and treat the sanitary sewage or deliver it to an adjacent system for treatment, the tightening up on sewerage at two municipal systems and the treatment of raw sewage from approximately 2,000 persons discharged to the river from two Ohio sanitary districts. A higher degree of sewage treatment for the larger municipalities may later be required.

The Mahoning River is probably the most grossly polluted stream in this part of the United States and little has been accomplished by the Ohio authorities to correct this situation. The problem involves sewage, organic industrial wastes, spent acids from large steel mills and phenols from four byproduct coke plants having combined capacities of approximately 13,000 tons per day. It is estimated in the Ohio River Pollution Report [House Document No. 266, pp. 419–424 (1944)] that the untreated sewage of 280,000 persons and industrial wastes equivalent to the sewage from another 150,000 persons, plus practically all of the untreated spent pickle liquors discharged to the Beaver River basin, are discharged to the Mahoning River within 10 or 15 miles of Youngstown. The oxygen requirements of the untreated sewage and industrial waste in this stretch of the river exceed the available oxygen even on minimum river flows of 300 cfs.

FIG. 3. Profile of Beaver River and Tributaries (Mahoning River to Warren, Ohio, Only)—Showing Populations (1940 Census) and Drainage Areas (Data From U.S.G.S. Topographical Sheets, Dept. of Forests and Waters, Hydrology Div.; and Engineers)

TABLE 3

Mahoning and Beaver River Phenol Results

U. S. Public Health Service Data
Sampling Period Dec. 4, 1940–Jan. 10, 1941
Average Discharge of Beaver River at Beaver Falls, 6,330 cfs.

River	Location of Sampling Point	Miles Above Beaver Falls	Number of Samples	Phenol, *ppb.*			pH	Iron, *ppm.*
				Maximum	Minimum	Average		
Mahoning	Above Warren	59.0	13	2	0	0.15	7.0	1.1
Mahoning	Above Niles	45.7	13	600	0	141	6.4	18.0
Mahoning	Youngstown (Mahoning Ave.)	34.8	13	800	10	223	6.4	13.0
Mahoning	Campbell at Youngstown Sheet and Tube Bridge	30.5	13	1,000	60	570	6.4	13.0
Mahoning	Struthers Bridge	29.1	10	2,000	90	929	6.5	16.0
Mahoning	Mt. Jackson Highway Bridge	17.0	11	1,800	50	685	6.6	9.0
Shenango	New Castle Viaduct	17.5	10	15	0	3.5	6.8	2.4
Beaver	Above Beaver Falls	0.0	11	230	35	108	6.7	2.3

Pennsylvania Department of Health Data
Sampling Period Jan. 12, 1945–Mar. 23, 1945

River	Location of Sampling Point	Miles Above Beaver Falls	Number of Samples	Phenol, *ppb.*		pH	Iron, *ppm.*	River Flow Youngstown, *cfs.*
				Maximum	Minimum			
Mahoning	Mt. Jackson Highway Bridge	17.0	7	1600	140	6.8	10.8	618

The discharge of phenolic waste waters from the byproduct coke plants has continued to produce intermittent objectionable taste and odor problems at the downstream Pennsylvania water works, principally during the cold months of the year. The installation of dephenolizing plants with the dephenolized liquors used for coke quenching, as is done at the world's largest byproduct plant at Clairton, Pa., may be the means of eliminating the objectionable condition at the water works. Table 3 shows the phenol results from surveys made by the U.S. Public Health Service and the Pennsylvania Health Department. The 1945 results show an improvement in phenol concentrations over the earlier survey, if river flows are considered; however, phenol concentrations, ranging from a minimum of 140 to a maximum of 1,600 ppb. at a point 20 miles below Youngstown and 18 miles above water works serving 55,000 persons, clearly indicate that further controls are necessary.

The Youngstown interests have been active in securing the construction of the Berlin and Mosquito Creek reservoirs, which, as previously mentioned, are multiple-purpose reservoirs for flood control and flow augmentation. These reservoirs, combined with the Milton Reservoir, are expected to maintain during peak temperatures river flows at Youngstown of from 300 to possibly 500 cfs.

Beginning in 1942, and continuing since for the normal low flow months of June, July, August, September and October, there has been an increase of approximately 9,000 per 100 ml. in the coliform density of the raw water at the Beaver Falls Municipal Authority water filtration plants, as compared with the same months during the previous four years. This coincides with increased Mahoning River flows occasioned by a change in the operation of Milton Reservoir in 1942 to keep the reservoir full in the spring of the year for maximum summer release of water, and beginning withdrawal of water from the Berlin and Mosquito Creek reservoirs in 1943 and 1944, respectively, plus better Pymatuning low flow controls. The increased river flows have increased velocities of flow, thus reducing the time of travel to the downstream water works, and have lessened the effects of the spent acids and iron salts from pickling liquors on the sewage discharged in the Youngstown area to this stream. Low flow augmentation in a case like this, without parallel sewage treatment, can be harmful to downstream water works by increasing the effect of upstream sewage on these plants. The heavy pollution of the Mahoning River and the Beaver River below the confluence of the Mahoning can only be corrected by adequate sewage and industrial waste treatment on the Mahoning in Ohio. Completing the Pennsylvania program at two municipalities where steps are now under way, as has previously been mentioned, will be helpful on the Beaver; however, there still remains the Mahoning problem with its malign effect on the Beaver River.

Allegheny River Basin

The Allegheny River drainage basin is the largest in western Pennsylvania. The principal tributaries are the Kiskiminetas and Clarion rivers and French Creek. There is no large population concentration on this basin in District "C." Coal mining and steel production are the most important industries, considering the Allegheny basin as a whole; however, this is not true of the large part of the basin located in District "C." Milk production and manufacturing, oil producing and refining, chemical industries, distilling, paper manufacturing, tanneries and a wide variety of industries operate in this area. Most of the mine drainage originating on the watershed is from the Kiskiminetas drainage basin. The Allegheny River upstream from the Kiskiminetas and the principal and most of the minor tributaries are alkaline. The Allegheny River and many of its tributaries are used as sources of the public water supply.

A sewage treatment program which has been carried on for some time now is beginning to show results. All of the municipalities on French Creek treat their sewage, with three of the plants giving complete treatment, including the largest municipality, Meadville. On the Allegheny proper, Franklin and Emlenton are operating primary sewage treatment works, and Warren, Tionesta, Oil City, Foxburg, East Brady, Kittanning, Applewold, Ford City and Freeport have employed engineers to prepare plans for sewage treatment. Most of these municipalities have constructed all or a part of the necessary intercepting sewers, have established financial programs to construct treatment works and have secured sites for treatment. Youngs-

ville, on Brokenstraw Creek, operates a primary treatment plant and Corry has recently purchased the site and submitted plans for a complete sewage treatment plant. Titusville and Rouseville have employed engineers to prepare sewage treatment plans and Titusville has passed a bond issue to construct the intercepting sewers and has purchased a site for treatment. Clarion, the only municipality in this district on the Clarion River, is operating a sewage plant. Brookville, on Red Bank Creek, and Sligo, on Licking Creek, have employed engineers to prepare sewage treatment plans. Five more municipalities will receive notices to prepare treatment plant plans. In addition, seven sewage plants are being operated on various small tributaries.

There are a total of 36 sewered municipalities on the Allegheny River or its tributaries in District "C," 13 of which now operate sewage plants. In addition, there are three sewage plants of complete treatment serving two large institutions and a large industrial plant. Fourteen additional municipalities have employed engineers to prepare sewage plant plans. Nine municipalities have constructed intercepting sewers in whole or part as a preliminary to treatment, and a number have financial programs to construct treatment works. Eleven of the municipalities employing engineers to prepare plans have purchased or are now purchasing sites.

From the industrial waste standpoint, considerable progress has been made on the drainage basin in this district. There are some interesting waste treatment works, consisting of: the largest and most complete TNT plant waste treatment facilities in the country; complete treatment at a large whiskey distillery, where the raw waste load is the equivalent of the raw sewage of a city of approximately 355,000 persons; complete treatment at a large cellulose acetate rayon plant, probably the only plant of its type in the United States; cyanide plating waste water treatment by chlorination; chromium removal facilities; more milk waste treatment plants than the rest of the state; oil separators; acid neutralizing facilities, etc. There still remains much to be accomplished, however, principally in improved control at oil refineries and oil production on limited small oil fields and treatment and/or improvements at scattered industrial establishments.

The most objectionable stream condition on the Allegheny River or its tributaries in this area is the heavy industrial pollution of the Clarion River in an adjoining district. The effects of this pollution are noticeable on the Clarion River through to the Allegheny River and on the Allegheny at times of low flow below the confluence of these streams. An understanding with a power company operating a hydroelectric plant on the Clarion River not to draw the Clarion Dam down in a short period at times of low flows in the Allegheny has helped this situation somewhat, but it has not corrected the pollution of the Clarion at its source.

From the mine drainage standpoint, Mahoning Creek, one of the larger Allegheny River tributaries, presents an interesting picture. Here, large mines, some of which are shaft mines, are being worked out and abandoned, plus limited mine sealing, and the amount of acid mine drainage discharged has been substantially reduced so that at present the sewage of the largest municipality is beginning to be noticeable on low flows in this stream. Fish life

in a limited way is again being found in parts of this stream.

The proposed Warren Reservoir, if constructed to provide flow augmentation as planned, will be of decided value to the Allegheny River, especially that part of the river between the Kiskiminetas and the Ohio, as well as the upper Ohio itself. Figure 2 shows the maximum monthly acidities of the Allegheny River at Aspinwall for the past ten years. It will be noted that the trend of the maximum monthly acidities during this period is toward an alkaline condition. The release of alkaline water by flow augmentation from the proposed Warren Reservoir would provide sufficient alkalinity to make the lower Allegheny alkaline for most of the months of maximum acidity for the period indicated. The reservoir would also be of value in providing reserve alkalinity in the pools in the lower Allegheny and the upper Ohio to minimize acid surges caused by runoff from the acid drainage basins without corresponding runoff from the alkaline basins.

Lower Ohio

The problem of the lower Ohio is substantially the same as the Metropolitan Pittsburgh district. This area comprises Beaver County, which has had a rate of growth exceeding the state rate for some years, partially because of the Ohio River and the excellent rail and river transportation facilities. The only water supply taken from the Ohio River in Pennsylvania is at Midland, where a complete new modern water filtration plant is being constructed. Steel and related industrial production represents the major industrial development in this county. There is little coal mining.

The discharge of acid mine drainage, principally from the Monongahela, Youghiogheny and the Kiskiminetas, has both adverse and beneficial effects on the Ohio River below Pittsburgh and in this district. Mine drainage contains mineral acids and iron salts which act as germicides. Without the mine drainage there would undoubtedly be a serious pollution situation on this part of the river. Mine drainage is harmful in that it makes this part of the river less desirable for all uses and adds to the cost of the users of the river water, whether it be for transportation, cooling or as a source of public water supply. Mine drainage also has a marked effect on this part of the river by the "flush-outs" which occur during some low Ohio River flows. Figure 5 shows the effect of rainfall and a flush-out on the Ohio River from the streams receiving heavy acid mine drainage loadings without corresponding runoff from the alkaline drainage basins. It will be noted that the discharge of the Youghiogheny and Monongahela carried out the acid mine drainage accumulated behind the various dams to the point where its effects were very noticeable on the Ohio River at the Montgomery Island Dam some 30 miles below Pittsburgh. The pH of the river water at that point dropped abruptly from 6.5 to an hourly low of 3.8 and returned later to a pH of 6.5 with more normal river discharge conditions. This phase of the mine drainage problem needs to be studied, as such a flush-out will be noted for miles down the Ohio River.

Recently the Beaver County municipalities along the Ohio River were instructed to prepare plans for sewage treatment, and even though these notices were issued prior to the notices to adjoining Pittsburgh and Allegheny

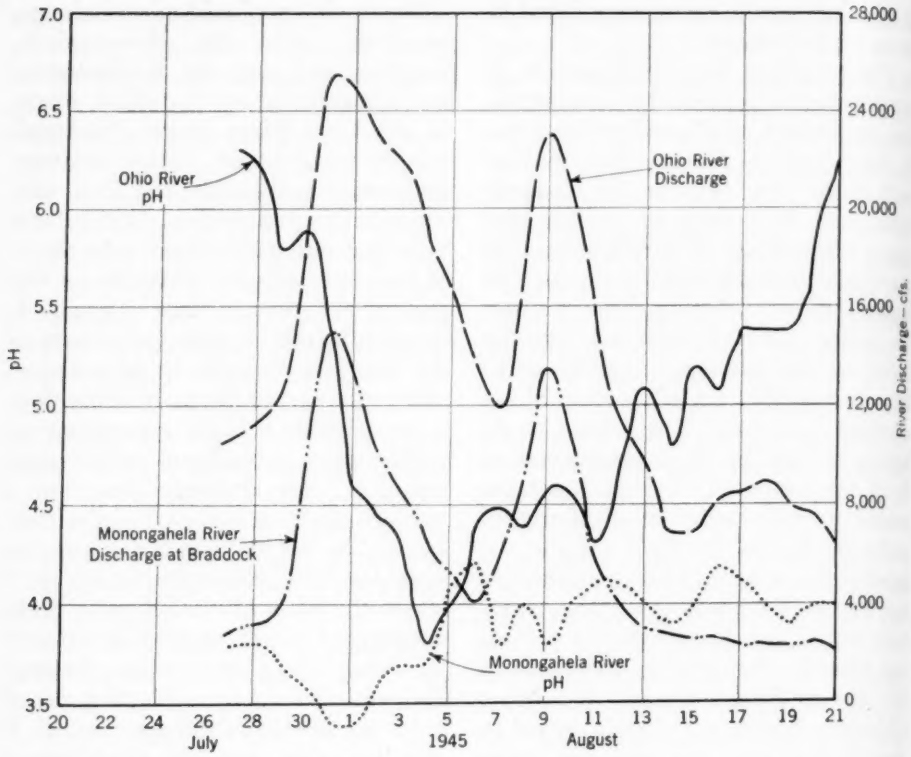


FIG. 5. Effect of Acid Flush-Out on Ohio River at Montgomery Dam

County, all of the larger municipalities have employed engineers to prepare treatment plans. Plans are being prepared by Ambridge, Aliquippa, Conway, East Rochester, Baden, Freedom, Rochester, New Brighton, Monaca, Harmony Township, Beaver and Midland. One primary sewage plant is now operating to serve a large industry along this part of the river.

From the industrial waste standpoint limited work has been done principally on taste- and odor-producing wastes. The three most important plants of this type are two dephenolizing plants for byproduct coke plant waste waters, and waste treatment facilities, which are now being completed at the largest synthetic rubber plant in the United States. The one dephenolizing plant was designed so that the dephenolized waste waters can be used at a future date for coke quenching as a means of reducing to a minimum the discharge of phenols to the river. The new dephenolizing plant has been designed to use the dephenolized waste waters for coke quenching. This latter plant will replace existing coke-quenching facilities. Waste treatment at the plant producing butadiene and styrene represents an interesting problem because of the large volume and the character of the waste waters. The waste waters are objectionable from the water works standpoint because of their ability to produce a peculiar taste and odor.

which are difficult and costly to remove if present in any amount. During initial operations of this plant, it was claimed that taste and odors were produced in the municipal water supplies as far downstream as Wheeling, W. Va.; however, after overcoming initial operating difficulties that involved operating a new plant above its designed capacity almost at the beginning because of the war emergency, training operators in a new complicated process, overcoming mechanical and other similar difficulties always present in new installations, and adding supplemental waste treatment or controls to the facilities first installed, this plant has since caused little trouble for downstream water works. It is expected that waste treatment facilities for taste and odor control will be completed shortly. These facilities are expected to effect a high reduction in taste and odors in the waste waters. The installation of "recovery and bottling up" facilities on one important waste water resulted in the recovery of aproximately 4,000 gpd. of low grade ether, which was previously lost in the plant waste waters.

Progress and controls in this part of the Ohio will be tied in with similar progress in the Pittsburgh area.

Summary

The major streams and many of their tributaries in District "C" are polluted in various degrees by sewage and/or industrial wastes and mine drainage in limited areas. The pollution problems vary from a local nuisance in an isolated case to a complicated case involving important water works, where sewage, industrial waste and acid wastes all contribute to the problem. Stream cleaning in this area should be considered from the standpoint of the major drainage basins, yet fitting these basin programs into the whole western Pennsylvania picture so as to secure the desired results. It is essential in this area that there be coordination and co-operation between the several states on the drainage areas in carrying forward the cleanup program unless only partial benefits are to result. The Pennsylvania ratification of the Ohio River Valley Water Sanitation Compact is undoubtedly a step toward that end. The cleanup program should be carried out primarily to improve the streams from the water supply standpoint, endeavoring to complete first those parts of the program benefiting the largest number of the public, or those parts of the streams where the greatest difficulty is experienced in producing safe and satisfactory public water supplies. A suggested order of importance is: (1) adequate treatment of sewage, (2) better controls over the discharge of taste- and odor-producing waters, (3) better controls over the discharge of industrial wastes causing water treatment difficulties, (4) mine sealing, (5) flow augmentation with emphasis on those reservoirs best fitting into the pollution control program, and (6) the treatment of other industrial wastes. Certain of these activities should be carried out concurrently in order to secure the desired results. Federal funds should not be provided to construct works capable of materially modifying river flow conditions to the detriment of downstream water works unless such improvement is accompanied by parallel and adequate treatment of objectionable wastes discharged to the stretch of stream under consideration.

Flow augmentation is important to pollution corrections in this area as in most cases it contributes alkalinity to

neutralize acids; dilutes the mine drainage discharged; smooths out slugs from acid mine drainage discharges or from unregulated industrial waste discharges; provides additional oxygenation during the critical stream flow period of the year, thereby increasing the assimilating capacity of the stream for organic wastes; limits temperature increases caused by large industrial users of the stream; and is of value for recreation, navigation and other purposes. The proposed Warren Reservoir on the Allegheny River and a reservoir on French Creek would be of greatest value in this district. Pollution control in parts of this area will be difficult because of the population density and complicated problem; however, it can be accomplished by a comprehensive program involving education and publicity, backed by active, intelligent and persistent effort to that end. Simplified ways and means of financing these improvements, including a continuing program of mine sealing, are essential to the program. Some hold that there is an obligation on the part of the state to participate in financing this program. Certainly such participation would assist greatly in carrying the program to completion.

New Developments in Water Rates

By Charles H. Capen Jr.

Chief Engr., North Jersey Dist. Water Supply Com., Wanaque, N.J.

Presented on Dec. 15, 1945, at the Four States Section Meeting, Baltimore, Md.

DURING much of the first week of any month, most households are confronted with a batch of mail adorned with plate glass fronts. It is a good old American custom and will persist as long as credit is extended—which will probably be much further in the future than any of us care to predict.

Perhaps a spirit of ennui existed originally when the first water bills were rendered. At any rate we have adhered strictly to the old saying that "In the matter of successful imitation, man is a monkey's superior." We all do the same thing, i.e., render bills not more often than every three months. There are, of course, the specific exceptions of large users which are commonly billed monthly.

It is the author's belief that one of the main reasons for the hesitancy of all water purveyors to establish a change in rates (unless it be downward) is the fact that water bills are paid quarterly and are usually of an amount sufficient to cause concern when an increase is incurred. This is not a plea for a change in billing, but merely a statement of fact. It may be fairly estimated that the average household bill is between $4.00 and $6.00 per quarter. An increase in rates, of say 10 per cent, would be immediately observed and the protests would be voluminous. On the other hand, if the bill were rendered monthly, a 10 per cent increase would hardly be noticed.

For some reason that is not wholly clear, electric and gas utilities have generally adopted the monthly billing system. Heretofore they have not been as much troubled with minor adjustments in rates, largely because the cost of production, particularly in the case of electric current, has been downward. This is said in spite of the many utility rate cases that have been before the public.

Rates After First World War

Between 1918 and 1925 there was an almost universal clamor for changes in the rates charged for water. To their credit it may be said that the private water companies persisted in their efforts in this direction and obtained a rational rate increase. In many instances the publicly owned supplies did not, and the resulting debacle of their financial structure in the early thirties was directly attributable to the failure to do so. Many of them were forced to place surcharges on water bills at a time when all other costs were at a low ebb. Certainly the reverse would have been much more gracious and would have been possible if the correct policy had been adopted earlier.

Future Rates

There is no doubt that the increased costs of labor and material have already had a noticeable effect on net incomes from water supply properties. It is the belief of the author that the

great wartime increase in gross income is the basic factor in deterring many operators from vigorously seeking a rate adjustment.

Already there are noticeable decreases in the use of water. It is customary in such instances, however, to find that the decrease is very largely industrial and in such brackets as not to cause a proportionate decrease of income. Thus, during the depression, loss in revenue often did not exceed half the reduction in water usage. In other words, while reduction in usage averaged perhaps 15 per cent, revenue loss was about 8 per cent. This showed clearly that the large variations are usually industrial.

When one considers how great the loss was in most other business ventures in the early thirties, it becomes pertinent to ask why water supplies, particularly those publicly owned, were in such bad financial condition. The answer lies very largely in two items: insufficient rates and large mandatory budget obligations. Of the first, a brief expression of ideas has already been given herein. Of the second, it may be pointed out that tremendous expansion of indebtedness in the late twenties created situations where as much as 75 per cent of all water income for some cities was being paid out for debt service. The peak of many of these payments arrived simultaneously with the depression. This left only 25 per cent of the revenue available for operation. An 8 per cent loss in gross revenue meant that operating expenses had to be reduced one-third in order to operate without a deficit. Small wonder then that water works men suffered severe cuts in wages.

In attempting to learn a lesson from past experience it is necessary to keep all these facts in mind, as well as to try to predict future conditions. While widespread strikes in the country would normally cast a curtain of gloom, the continually rising trend in wages, costs and demand for goods does not indicate any serious industrial let-down. Economists seem to believe that many of the strikes will be settled early in 1946 and that labor will be getting a higher rate of pay than before the war. The bugaboo of take-home pay is beginning to lose some of its effectiveness, partly because of diminishing war bond subscriptions and partly because income tax deductions not only may be less but also are becoming better understood, or at any rate more readily accepted.

Generally speaking, water works men are looking for a gradual resumption of water consumption up to a point at least exceeding that of the prewar period, even if not equal to wartime peaks. Most water supplies have deferred large expansions and some are in a far less favorable situation to meet such demands than in the late twenties. It is only natural to suppose that the pent-up measures of expansion will soon become realities. This will call for more bond issues, more personnel and, most important, greater costs.

More often than not, water supply systems do not build up large financial reserves. The private companies are skeptical of government attitudes and anticipate inroads on surplus or on profits. The public departments fear a raid on their treasury to eke out the tax budget, and often it is in the nature of a very substantial contribution to the city coffers—not a mere token payment. Thus there arises the frequent necessity of adjusting rates to fit immediate circumstances. No one can

deny that such practice is indefensible, but nevertheless it exists and probably will continue.

Wholesale Water

In many areas in the United States water is sold at wholesale to entire municipalities. These cases call for a special consideration. They vary from the usual problem of rates that industrial users are charged because frequently there is involved the transfer of water from one transmission system to another without reference to distribution costs.

One of the most complicated of these situations exists in northern New Jersey where some 14 per cent of the metropolitan area receives water which is purchased wholesale from other communities or companies. There are 33 separate communities and two water companies which obtain all their water by this method, in addition to several that receive parts of their supply similarly. In all there are over 50 separate and distinct instances in which water is so billed and paid for in this one area. The prices vary from $77.50 to $300 per mil.gal. Generally speaking, the large users buy water for $100 or less per mil.gal., with an average around $85, while most of the small users pay $150 or more, with an average around $175. The variations are much wider and more erratic among the smaller users.

The influence of such cases is most important on the rates to be charged the retail consumers, largely because of the fact that these wholesale prices rarely are reduced but frequently are increased. The municipalities so served can never hope to pay off indebtedness on the source of supply and thus receive an ultimate benefit in reduced rates. Usually they are not geographically situated so as to be able to own a source of supply and cannot afford to purchase a share of an existing one.

The individual user always pays these costs. It is difficult to evaluate all the factors involved to show a reasonable comparison, but it has been found from frequent excursions into this field that the retail rate, to be self-supporting, usually has to be at least twice the wholesale rate and more usually is nearer three times that figure.

Individual users outside a regular area (usually defined by municipal boundaries) are charged at rates varying all the way from the same unit cost to one and one-half times the cost and there are believed to be instances where greater ratios have been employed. Private companies are not usually plagued by the same considerations as municipalities. A plea can well be made here for a more general criterion that could serve as a guide for those dealing with this perplexing problem. Frequently it consumes more time and study than the revenue justifies, but it is nevertheless a case that must be considered.

The Problem

Most water works men hesitate to try to overcome public resentment to a large change in residential rates. Yet this is precisely what is apt to happen unless the expansions of the postwar period can be met out of financial reserves or unless the saddling of disproportionate debts is to be re-enacted.

In 1923 a Committee of the A.W.W.A. submitted a report advocating steps and ratios for various types of service. The author has drawn attention on more than one occasion in the

past to the fact that little or no attention has been paid to this recommendation. The problem therefore is for each system to work out an equitable arrangement of rates and then to go to bat to make it stick.

Role of Industrial Water

Industries that require large quantities of water shy away from localities that charge high rates for water. There are too many instances of this known to all water men to necessitate any enumeration here but some outstanding examples might well be mentioned.

A large company engaged in making cellophane is reported to have selected a site in Mexico for future development for two primary reasons: first, it requires vast quantities of water (reported to be as much as 400 mgd.) and secondly, the question of treatment of the trade wastes has not been raised. A large chemical industry in New Jersey contemplated expansion of its plant and made overtures for obtaining a low-priced industrial water. Negotiations failed and the plant is to be located in another state.

New York City is the center of myriads of small industries, but few large users of water ever move there. One reason is that few companies can afford to pay at the rate of $200 per mil.gal. for any extensive supply. Furthermore, New York is not alone in this situation, as may be readily discerned by scanning the rates of other cities.

If industry is to be encouraged to remain or to expand in many of the present locations, or if new industries are to be persuaded to enter metropolitan areas, then it is obvious that either they must be of the type that use little water or the rates must be attractive.

Comparison With Other Utilities

Quite often persons not familiar with the trade ask why water rates cannot be arranged to give a set of steps similar to those commonly employed by electric utilities. Typical electric bills to all types of users were reviewed and it was found that the ratio of maximum residential rate to minimum industrial rate is ten to one. This is rather typical of many electric rates and is obviously a far greater ratio than ordinarily exists with water supplies.

On the contrary, a study was made of illuminating gas rates of a large gas-producing utility. It was found that the residential rate begins at a $1.00 minimum for 400 cu.ft. per month, or theoretically 25¢ per 100 cu.ft. Actually this is partly a service charge. Thereafter the steps start at 11¢ per 100 cu.ft. and reduce to 5¢ in the higher brackets of usage. Wholesale rates begin at $100 minimum for 100,000 cu.ft., i.e. 10¢ per 100 cu.ft. and reduce to 3.5¢ when the quantity is in excess of 500,000 cu.ft. per month.

A further investigation was made of this case because it seemed possible that the gas and water costs might have considerable in common. It was finally learned that the gas rates mentioned herein do not allow any profit when dealing with large consumers. The history of the case was that during the depression the company had a large reserve producing capacity. In order to keep this in operation, a campaign to foster household and industrial use of gas was initiated. It was eminently successful—so much so that when the war needs were added to the greatly enlarged house heating demand, the company found itself straining its capacity and at costs which barely met the out-of-pocket costs, to say nothing of amortization.

It is axiomatic that situations such as this apply with equal force in the instance of water supplies. Selling water at out-of-pocket costs may be all right until a drought occurs—then it is dangerous.

The Solution

The solution to this problem lies in the direction of either producing and selling more water without increasing overhead costs materially or in establishing low-cost industrial supplies. Much may be said in favor of the first method, particularly with the low interest rate at which improvements may be financed today. The deterring factors are those of high labor and material costs. In the long run the ability to take advantage of producing and selling more water cheaply should work to the advantage of those supplies which were perhaps a little over-optimistic in the late twenties and then, because of overexpansion, took it on the chin financially during the depression.

Generally speaking Jupiter Pluvius was rather kind to the country as a whole during the high peak uses of the war period. Partly because of this and partly because of some few plant additions made during the war, there appears at the moment to be a fairly reasonable reserve capacity in many sources. To place this water on the market by means of suitable rates could readily be the instrument by which industries could be induced to look favorably on locations where such water is available. If this is done it will aid in the postwar development period. The extent to which it will aid depends partly on the facilities that may be available and partly on the willingness of water works managers to recognize the necessity for reviewing their rate schedules.

Possibly one of the earliest examples of the second method, that of a low-cost industrial supply, was instituted by Alexander Hamilton in 1791, when he formed the Society for the Establishment of Useful Manufacturers (S.U.M.) at the Great Falls of the Passaic River at Paterson, N.J. This enterprise is still in existence and was just recently acquired by the city. Both water and power were furnished.

In 1850 the Dundee Water Power and Land Company built a dam on the Passaic River a few miles below the Falls and furnished water for power and industrial uses via a canal. Originally a mill power (about 3 mgd.) cost $700 per year. The canal still operates and water is sold on various bases averaging around $7.50 per mil.gal.

A few years ago, three large industrial concerns built a supply on South River near Spotswood, N.J., to furnish water for their mutual benefit. The delivery in recent years is said to have been about 15 mgd.

At present the state of New Jersey is rehabilitating the old Delaware and Raritan Canal as a channel for carrying Delaware River water over to the industrial area in the Raritan River valley. This work is now in progress and it is estimated that 75 mgd. will be available from this source some time next year. The contemplated schedules of charges now under consideration included at first one in which the rate would be $25 per mil.gal. for the first 250,000 gpd. and reducing to $5 per mil.gal. for everything over 16 mgd. A more recent schedule considered would start at $20 per mil.gal. and reduce to $10.

The Panther Valley Water Company, which furnishes water to the

Lehigh Coal and Navigation Company at $30 per mil.gal. is another example. The output is about 10 mgd.

Perhaps the best known in the East is the industrial water supply for Birmingham, Ala., which furnished 34 mgd. in 1944 with rates starting at $70 per mil.gal. for the first 100,000 gpd. and reduced to $20 per mil.gal. for all over 10 mgd.

It is in the far West that canal projects have really come into their own. Many of these are for irrigation and other uses. One outstanding example is that of the Contra Costa Canal in the Central Valley Project of California. Approved in 1935, construction was carried on under the Bureau of Reclamation. Charges are based on U.S. operation and maintenance costs, plus an operating contingency, collectible in advance. These costs for 1944 were nominally $13.95 per mil.gal. for large industrial, municipal and agricultural users. Other agricultural water costs $18.40 per mil.gal.

Conclusions

Most water rates to large users are too high to appear attractive to industries using considerable quantities.

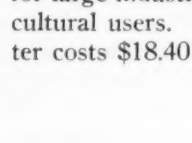
The following methods are suggested to those who wish to meet this situation in order to attract industries:

1. Review and revise the scale of rates so as to bring the large user cost as low as possible and consistent with actual costs and a reasonable profit.

2. Construct such low-cost additions to supply as may be feasible to bring down the average cost of producing the water to the point where the price will be favorable.

3. Take advantage of low interest rates to make such other improvements as may be necessary to facilitate this program.

4. Construct or join in construction of such industrial supplies as may be found desirable or necessary. (*Note:* This is said with due deference to the important matter of cross-connections.)



Chicago's Sale of Water to Outside Municipalities

By William A. Weigel

Asst. Engr., Water Pipe Extension Div., Water Dept., Chicago, Ill.

Presented on Oct. 30, 1945, at the Illinois Section Meeting, Chicago, Ill.

THE city of Chicago and municipalities adjacent to the city receive their water supply from Lake Michigan through six intakes 2 to 3 miles off shore. The water passes through 65 miles of tunnels in solid rock to twelve pumping stations by direct pumping into 3,883 miles of 6- to 54-in. mains.

The total annual average daily pumpage of the Chicago Water Works for the year 1944 was 977,265,000 gal., of which 60,642,000, or 6.2 per cent was delivered and sold to municipalities at the city limits.

By the terms of Sec. 26 of the Sanitary District Act (para. 348, page 1351, chap. 42, Illinois Revised Statutes (1943)) the city of Chicago for over 36 years has been furnishing water to municipalities and is now supplying water to 40 municipalities having an estimated population of 387,000.

The act reads as follows:

Whenever in any such sanitary district there shall be a city, incorporated town or village, which owns a system of water works and supplies water from a lake or other source which will be saved and preserved from sewage pollution, by the construction of the main channel, drain, ditch or outlet herein provided for, and the turning of the sewage of such city and district therein, and there shall be in such sanitary district any territory bordering on any such city, incorporated town or village, within the limits of another city, incorporated town or village, which does not own any system of water works, at the time of the creation of such sanitary district then upon application by the corporate authorities of such latter named city, incorporated town or village, the corporate authorities of such city, incorporated town or village, having such system of water works shall furnish water at the boundary line between such municipalities by means of its water works to the corporate authorities asking for the same in such quantities as may be required to supply consumers within said territory, at no greater price or charge than it charges and collects of consumers within its limits for water furnished through meters in like large quantities.

Provided, however, that where any such latter named city, incorporated town or village has no territory bordering upon such city, incorporated town or village so owning a system of water works and supplying water as aforesaid, such latter named city, incorporated town or village may receive water in the same manner and under the same conditions as though it had territory bordering upon such municipality owning a system of water works and supplying water as aforesaid; provided such latter named city, incorporated town or village builds or causes to be built suitable and sufficient water mains to the limits of such city, incorporated town or village so owning a system of water works and supplying water as aforesaid to connect with the water mains and receive the water from such city, incorporated town or village so owning a system of water works and supplying water as aforesaid.

For a municipality to obtain a supply of city water it must first make written application to the Commissioner of Public Works, submitting the following information:

1. Quantity of water required—annual average daily and maximum requirement for any one day to be used during the next 10 years.
2. Size and location of connection desired to city main.
3. Present population and estimated population for the next 10 years.
4. Size and route of connecting main to city limits.
5. Capacity and character of existing and proposed storage facilities.
6. Size and location of emergency water connections with other municipalities and corporations.
7. Map of present water distribution system, together with the extent of its corporate limits.
8. Amount of total annual water revenue and expenditures.
9. Amount of cash on hand, bonds outstanding and additional bonds that can be raised.
10. Copy of last audit report of water fund.

Upon receipt of application by the Commissioner of Public Works for a supply of water by municipality, the commissioner consults with the city engineers regarding the feasibility of furnishing the water supply requested.

Processing of Applications

A copy of the application for water supply by the municipality is forwarded to the area engineer for field inspection, report and recommendation. The field inspection determines the point of connection to the city water main, and from flow tests and pressure gage readings, together with studies of the city water main distribution system, it is determined whether or not the distribution system should be reinforced to deliver the amount of water requested.

Conferences are held between representatives of the municipality requesting water and of the city for the purpose of discussing the provisions of the proposed water supply contract at various times before the execution of the contract.

After the report from the area engineer has been received stating that the quantity of water requested is available and recommending the size and location of the connection to the city main for said supply, a form of council order or ordinance is prepared and sent to the Corporation Counsel for approval as to form and legality. This council order, or ordinance, requests that the Commissioner of Public Works be authorized and directed to enter into a contract for a period of not more than 10 years with the municipality located within the Sanitary District of Chicago for furnishing from the city of Chicago water mains at the city limits, at a designated location, a supply of water to the municipality, not to exceed an annual average daily of a specified amount of water but not to exceed a specified amount in any one day of the year as may be required by the municipality to supply consumers of water within its territorial limits; all water to be taken from the mains of the city of Chicago under conditions and provisions to be prescribed by the Commissioner of Public Works.

Making City Extensions

Should the report of the area engineer, on the request for a supply of water to a municipality, state that the water main system at the point of connection requires reinforcement by the laying of water mains in order to de-

liver the quantity of water desired, it is then necessary for the department to request the City Council for money, either from current funds or money to be appropriated in the next year's appropriation ordinance to defray the cost of the water main extensions. The authorization to spend the money for the cost of installing the water mains is embodied in the council ordinance, together with a request for the authority to enter into the water supply agreement.

In the preparation of the proposed council order or ordinance by the office of the Corporation Counsel, the engineers of the water distribution system are consulted as to the engineering provisions of the proposed contract. After the proposed council order or ordinance has been approved by the Corporation Counsel as to form and legality, it is submitted to the Commissioner of Public Works for his attention and to be forwarded to the chairman of the Committee on Finance recommending that it be passed by the City Council.

The recommended form of council order or ordinance is referred by the chairman of the Committee on Finance to the chairman of the Subcommittee on Water Supply for report and recommendation. Meetings are arranged to discuss the proposed council order or ordinance and the proposed form of contract with representatives of the city and municipality to clarify any of the provisions. After due consideration by the Subcommittee on Water Supply, and when approved, the proposed council order or ordinance is recommended to the chairman of the Committee on Finance for passage by the City Council at its next regular meeting. At this meeting the order or ordinance is deferred and ordered published to be voted on at the next regular meeting of the City Council. After passage by the City Council of this authority, a draft of proposed contract is prepared and submitted to the Corporation Counsel for approval as to form and legality. In preparing the final draft of the proposed contract by the office of the Corporation Counsel, the engineers of the water distribution system are consulted as to the engineering provisions of the same.

After the council order or ordinance granting authority to the Commissioner of Public Works has been passed by the City Council to enter into a contract with the municipality for a supply of water, the plans and specifications for water works improvement which have been submitted to the Commissioner of Public Works by the municipality are examined by the engineers of the water distribution system and the Water Safety Control Section. The municipality is notified by letter of any change or corrections required in the plans and specifications and after they have been made, approval is given by the Commissioner of Public Works.

After the proposed contract has been examined and approved by the engineers of the water distribution system, it is submitted to the Commissioner of Public Works with the recommendation that it be forwarded to the officials of the municipality for execution, who in turn have a resolution adopted authorizing their officials to enter into the contract. After the municipality has signed the contract, it is returned to the Commissioner of Public Works for signatures and execution by the city officials.

The contract is executed in quintuplicate and distributed to the municipality and the Commissioner of Public

Works, Comptroller, Bureau of Water and the Water Pipe Extension Division, all of the city of Chicago.

Contents of Contract

The contract for sale of water to municipalities contains a number of provisions, of which the following are most pertinent:

Service To Be Furnished

The city agrees to furnish to the municipality and the municipality agrees to purchase and take from the city under the terms of the contract, a supply of water through metered connections authorized by the Commissioner of Public Works from the city's water mains at the city's limits to be used by the municipality in supplying water to consumers located within its limits.

Quantity

The supply of water to be furnished shall not exceed an annual average daily of a specified amount of water but not to exceed a specified amount in any one day of the year during the period of the contract.

Rates and Discount

The rates to be charged the municipality for filtered water or unfiltered water shall be the rates fixed by the ordinance of the city now in force, or which may hereafter be amended for water furnished through meters in like large quantities, and the municipality shall be entitled to the same discount or benefit allowed to metered customers of the city, as provided by the ordinance of the city now in effect.

Period of Contract

Contract shall be in force and continue in effect for a period of 10 years.

Meters

The meters measuring and controlling the supply of water shall be located in or near the city limits at a location to be approved by the Commissioner of Public Works of the city and the control valves shall be located within the city, and such meters and valves shall at all times be under the control of the city, and the full and complete protection of such meters shall be the obligation of the municipality.

The properly authorized officers, agents and representatives of the city shall at all times have free access to the meters and all other facilities.

If at any time the meters shall fail to register correctly the quantity of water furnished and taken, the estimated amount of water furnished and taken shall be determined according to the Municipal Code of the city of Chicago.

Terms and Conditions of Service

The municipality, at its own cost and expense, shall provide, make and keep in repair all feeder mains, connections, meter vaults, receiving tank or tanks, booster or other pumps, and slow-acting valves, or other appliances deemed necessary by the Commissioner of Public Works of the city at the point of connection.

The municipality shall provide, install, maintain and operate, at its own cost and expense, at such locations as shall be designated by the Commissioner of Public Works of the city, the following: a shut-off gate or gates, reservoir or reservoirs of sufficient capacity to store not less than one day's supply of water; receiving tanks or tanks, booster or other pumps, slow-acting valves, and such other appliances or devices as may be required by the Commissioner of Public Works. The mu-

nicipality agrees to maintain and operate the reservoir to its full capacity at all times during the period of the contract.

The water supply furnished shall be drawn by the municipality at an even rate of flow throughout 24 hours of each day during the period from October 1 of each year to May 15 of the succeeding year, and at an even rate of flow throughout 20 hours from 10 P.M. of each day to 6:00 P.M. of each succeeding day during the period from May 15 to October 1 of each year. The municipality agrees to draw no water from 6:00 P.M. to 10:00 P.M. of any day during the period from May 15 to October 1 of each year unless expressly authorized in writing so to do by the Commissioner of Public Works of the city. It is agreed that the Commissioner of Public Works of the city shall have access to and the right to adjust and control valves and meters in order to limit the flow of water.

The municipality agrees to comply with any and all sanitary regulations of the city applicable to cross-connections and dual water supplies. The municipality agrees that the duly authorized engineers and inspectors of the city shall be permitted to make inspections and require tests for tightness of the piping of the water works installations, and of all plants or other buildings of water users within the territorial limits of the municipality.

The municipality agrees to prevent excessive use and waste of water.

In order to safeguard its water supply received and the city's water supply, the municipality agrees to maintain a safe water supply throughout its system and to provide, maintain and operate at all times during the period of the contract, chlorinating equipment or other equally effective health protecting process.

The municipality agrees not to resell or permit any water furnished to be used to supply any other municipality, or consumer of water located or residing outside the territorial limits of the municipality, except if and when it should be specifically authorized so to do by the City Council of the city.

The city shall not be responsible in damages for any failure to supply water or for interruption of the supply. The municipality agrees to save and keep harmless the city from any and all damage to real and personal property occasioned or caused by the making of the water connection or connections, or caused by the furnishing of water.

If the municipality shall refuse, neglect or fail to pay promptly the water bills rendered for the water supplied it, within the time prescribed by the ordinance of the city, or if the municipality shall fail to comply with or perform any of the conditions or obligations on its part to be complied with or to be performed, then the city shall have the right to shut off the supply at the expiration of 5 days after the giving of due notice, and to terminate the contract unless within 5 days the municipality makes good such failure.

No assignments or transfer of the contract shall be made by the municipality.

No officer, official or agent of the city has the power to amend, modify or alter the agreement or waive any of its conditions or to bind the city by making any promise or representation not contained in the contract.

The authority of the officials of the city to execute the agreement is evidenced by the order of the City Council of the city of Chicago passed on a certain day and published in the Journal of Proceedings of the City Council.

The authority of the officials of the municipality to execute the agreement is evidenced by the resolution passed by the officials of the municipality at a regular meeting held on a certain day.

The contract is signed by the City Comptroller, the Mayor, the City Clerk, the Corporation Counsel and the Commissioner of Public Works of the city of Chicago; and the Mayor or President and the Clerk of the municipality.

Summary

Outlined above is the procedure in the preparation of a contract from the time a request is received for a water supply until the signing of the agreement. Also enumerated are some of the significant provisions contained in the contract.

As to the future, the water supplies of many municipalities in the Chicago area are rapidly being depleted because they have depended upon deep wells for their source. These wells are failing due to the general lowering of the water table. The recession or drawdown of water in wells in the Chicago area is an annual average of 6 ft. for the past 50 years.

Another expense and inconvenience is the excessive hardness of water obtained from wells. The greatest monetary savings are in soap and cleaning compounds, as well as savings in life of linens and clothing. By using the softer Lake Michigan water repairs to plumbing will be at a minimum and installations should last many years. Scale elimination in piping systems will result in large savings on heat and maintenance. With an abundant supply of suitable soft water at the customer's faucet, more water will be used, thereby increasing revenue to the municipality. Excessively hard water retards the growth of municipalities because, other things being equal, industry will locate in a municipality with a soft water supply in preference to one with a hard supply. In addition to receiving a relatively soft water from Chicago, the municipality is assured of a reliable source, for Chicago uses Lake Michigan water of which there is an abundant quantity. It is inevitable that municipalities in the Chicago area must obtain Lake Michigan water for their water supply. Under the existing statutes, the municipalities within the Sanitary District desiring Lake Michigan water must bring their supply line to the city limits of Chicago. This limiting procedure is largely not an engineering problem but a legal matter which may soon be modified with the help and co-operation of the municipalities.

Water Problems in Saskatchewan

By J. G. Schaeffer

Director, Div. of Sanitation, Dept. of Public Health, Regina, Sask., Can.

A contribution to the Journal

MUNICIPAL water problems in the prairie provinces are probably more perplexing than in other parts of the Dominion, and in Saskatchewan they may be considered particularly acute. Although the province has an area of approximately 260,000 square miles and extends northward from the International Boundary a distance of some 760 miles, only the northern half has an abundance of surface waters. The southern half is almost devoid of lakes and streams, and, with the exception of a few settlements, the entire population is found in this area.

The only stream of any magnitude in the south is the Saskatchewan River, which consists of two branches, the north and the south. Their confluence is a few miles east of the city of Prince Albert and just slightly south of the geographic center of the province (Fig. 1). The few lakes are highly mineralized or so saline that they cannot be used for any purpose. Subsurface supplies, where available, are secured from wells ranging from 100 to 200 ft. in depth. The aquifer is usually an unconsolidated glacial deposit. Solid rock is not encountered in the southern half of the province, although what is known as bedrock may be found at depths of 300 ft. or less. Some glacial deposits in the upper horizons produce an abundance of water which is medium soft in character, but the average subsurface water is high in calcium, magnesium and sodium sulfate.

The scarcity of surface water, however, forces municipalities to depend on underground supplies. Out of 39 large and small municipal water works systems in the province less than one third derive their supply from surface water. The city of Regina, with a population of approximately 60,000, is entirely dependent on wells. Although the water is hard, averaging about 650 ppm., the quantity has been adequate up to the present. Nevertheless, reserves are decidedly limited. Moose Jaw, some 40 miles to the west, has long experienced a water shortage. Until recently it has depended on a few wells and an infiltration gallery, none of which has an abundant supply.

As early as 1910, engineers investigating the water supply situation at Moose Jaw suggested the Saskatchewan River as the ultimate source of supply. From time to time, in the succeeding years, further surveys resulted in similar reports and recommendations. In 1919–20 a commission was set up by the government for the purpose of studying and reporting on the feasibility of utilizing the Saskatchewan River as a source of water supply for the cities of Moose Jaw and Regina and surrounding areas. The commission reported favorably and estimated the ultimate cost to be approximately

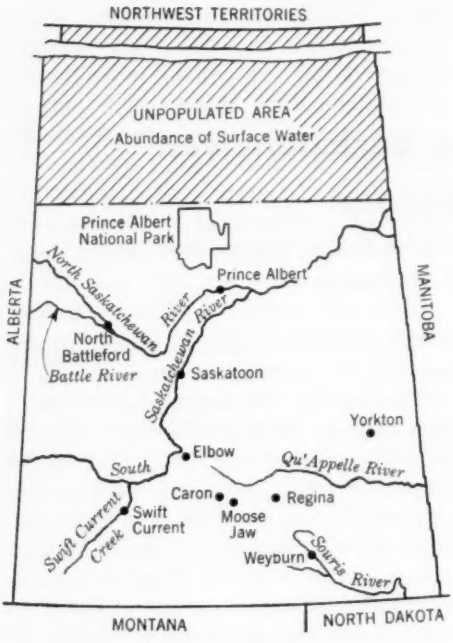


FIG. 1. Province of Saskatchewan

$10,000,000. Nothing came of the recommendations, however, and the matter lay dormant for many years.

Under the provisions of the Prairie Farm Rehabilitation Act, adopted in the middle thirties, further consideration was given to the Saskatchewan River water scheme. Engineers appointed under the act saw large-scale irrigation possibilities with the development of dams on the river. As a preliminary undertaking, and to relieve an acute water shortage at the time, it was recommended that an open ditch be constructed from about Riverhurst to Caron, a distance of 70 miles. After pumping the water to a reservoir on the height of land adjacent to the river, it was feasible to convey the flow to Caron, 20 miles west of Moose Jaw, by gravity. The proposal was approved and for the past four or five years the city's major source has been Saskatchewan River water (Fig. 2). The open ditch discharges onto a previous area from which the water is picked up through sandpoints and pumped to the city. This method eliminates the necessity of treatment, other than chlorination.

Figure 3 shows a profile of the pipeline and canal.

It is generally recognized that the city of Regina must eventually look to the Saskatchewan River for its water supply. The original recommendation that water be piped to Moose Jaw and Regina is receiving serious consideration at the moment and constitutes one of the larger postwar projects in the water works field. There is also a proposal to divert water from the Saskatchewan River to the Qu'Appelle River. This would serve a large area from a point north of Moose Jaw to the Manitoba boundary. The present flow in the Qu'Appelle is negligible.

Saskatoon, the second largest city in the province, is located on the south branch of the Saskatchewan River and has no water problem, other than treatment. The minimum flow at Saskatoon is about 1,000 fps. The maximum flow is many times that figure. An overflow dam was constructed at Saskatoon just before World War II, but it was not primarily built in connection with the water supply.

The city of Prince Albert is likewise on the Saskatchewan River, but on the north branch. Shifting sand bars are the city's only concern but up to the present no undue difficulty has been experienced. Increased treatment facilities are a postwar project.

Although the city of North Battleford is also on the north branch of the river, the water supply is secured from wells. This system, however, has not

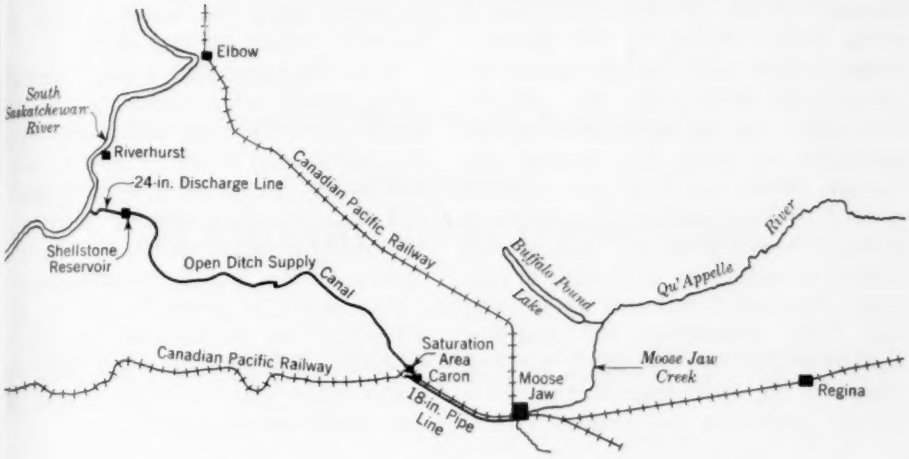


FIG. 2. Saskatchewan River Project—Moose Jaw Water Supply

proven entirely satisfactory, as the supply is limited and reserves have not been located. In addition, the iron content is so high that removal is necessary. Without a dam or series of dams in the river, the successful operation of an intake is problematical because of low water conditions at times, and the constantly shifting sand bars. It is the author's opinion, however, that, with an appreciable growth of the city, the river will be the ultimate source of supply.

The city of Swift Current secures its water supply from Swift Current Creek. The supply is ample, due largely to the impounding reservoirs and control works constructed under the provision of the Prairie Farm Rehabilitation Act. The present treatment plant, completed in 1936, is entirely inadequate for the increased consumption and additions in the near future are contemplated.

Of the smaller cities, Weyburn has probably experienced the most serious problems. Water is taken from wells less than 100 ft. deep. No other aquifer has been encountered in spite of extensive drilling operations. The supply is inadequate at best and, due to the high iron content of the water, well screens last only a short time before removal or cleaning is necessary. The Provincial Government maintains at Weyburn a large mental institution which depends on the city's system for water. The Souris River passes through the city but there is no flow except during the spring runoff. During the early war years a dam was con-

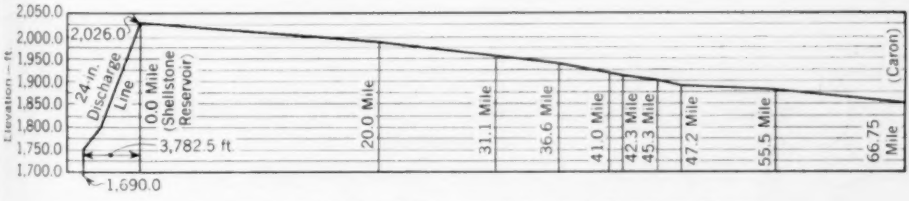
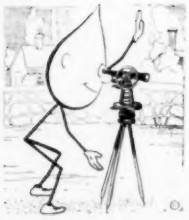


FIG. 3. Profile of 24-in. Discharge Line and Canal to Caron

structed on the Souris some 5 or 6 miles below Weyburn, the purpose being to store water for the mental institution as well as the city. Before this water can be utilized it will be necessary to divert the treated city sewage below the dam and provide some 6 miles of water force main and a water treatment plant. The sewage diversion, consisting of 5 miles of concrete pipe and 2 miles of open ditch, has been completed, but pumping equipment has not yet been installed. Plans for the water treatment plant are in the course of preparation. It is hoped to have the water system in operation before the end of 1946.

It is anticipated that a large number of the smaller urban centers will install water works systems within the next few years, even though the best available water, for the time being at least, will be somewhat inferior from the mineral salt point of view. In the opinion of the author, greater consideration must be given the future development of surface storage, even though such schemes may be costly and under other circumstances would be considered uneconomical.



American Water Works Association

Tentative

STANDARD SPECIFICATIONS

for

COLD WATER METERS—CURRENT TYPE

These "Tentative Standard Specifications for Cold Water Meters—Current Type" are based upon the best known experience and are intended for use under normal conditions. They are not designed for unqualified use under all conditions and the advisability of use of the material herein specified for any installation must be subjected to review by the engineer responsible for the installation in the particular locality concerned.

Approved as Tentative by the Board of Directors of the A.W.W.A. on January 14, 1946

Copyrighted as Part of the April 1946 Journal of the American Water Works Association

First Printing, April 1946

AMERICAN WATER WORKS ASSOCIATION
Incorporated
500 Fifth Avenue, New York 18, N.Y.

Prepared by

Water Works Practice Committee 7M

Personnel

SAMUEL F. NEWKIRK JR., *Chairman*

EDWARD V. BUCHANAN
JAMES G. CARNS JR.
A. P. KURANZ
H. W. NIEMEYER
H. V. PEDERSEN
GEORGE READ
GEORGE J. ROHAN
GEORGE C. SOPP
L. S. VANCE
W. VICTOR WEIR

Table of Contents

General—Section 2–1

SECTION

Scope 2–1.1
Kind and Type 2–1.2

Capacity, Size and Length—Section 2–2

Capacity 2–2.1
Size 2–2.2
Length 2–2.3

Design—Section 2–3

Cases 2–3.1
External Bolts 2–3.2
Connections 2–3.3
Registers 2–3.4
Register Boxes 2–3.5
Intermediate Gear Trains 2–3.6
Measuring Chambers 2–3.7
Impellers 2–3.8
Strainers 2–3.9
Seal Wire Holes 2–3.10

Registration—Section 2–4

Pressure Test—Section 2–5

Workmanship and Materials—Section 2–6

Rejected Meters—Section 2–7

NOTES

Tests 1
Testing Equipment 2
Care of Meters 3
Bronze 4
Rubber 5

Tentative

Standard Specifications for Cold Water Meters

Current Type

Section 2–1—General

Sec. 2–1.1—Scope

These specifications embrace the various types and classes of cold water current meters for water works consumer service and cover the materials and workmanship employed in their fabrication.

Sec. 2–1.2—Kind and Type

The kinds of meters covered are service meters of the current, velocity or turbine type. These meters register the flow by recording the revolutions of a water impeller or wheel which is set in motion by the force of the flowing water coming in contact with the impeller or wheel blades.

Section 2–2—Capacity, Size and Length

Sec. 2–2.1—Capacity

Capacity or delivery classification shall be the quantity given in Table 1, Column 2, and is determined by the quantity delivered at the permissible maximum loss of head.

Meters shall have a loss of head not exceeding 20 psi., when the rate of flow is that given in Table 1, Column 2.

Sec. 2–2.2—Size

The size of the meter given in Table 1, Column 1, shall be in terms of the nominal size of opening in the inlet and outlet spuds or flanges of the meter.

Sec. 2–2.3—Length

The minimum and maximum overall lengths of the meter, face to face of spuds or flanges, are given in Table 2, Columns 2 and 3. A filler piece can be inserted to increase the length of the shorter meter, if required, but the meter itself must not be shorter than the minimum length given in the table.

Section 2–3—Design

Sec. 2–3.1—Cases

The outer cases shall be of bronze composition or of cast iron protected by a non-corrosive treatment. Castings shall not be repaired, plugged, brazed or "burned in."

All meters shall have cast on them, in raised characters, the size and model. The direction of the flow through the meter shall be properly indicated. Meters shall be designed for easy removal of all interior parts without disturbing the connections to the pipeline.

TABLE 1

Current Meters

(1) Meter Size, *in.*	(2) Safe Maximum Operating Capacity,* *gpm.*	(3) Maximum Loss of Head, *psi.*	(4) Minimum Test Flow, *gpm.*	(5) Normal Test Flow Limits, *gpm.*	(6) Speed of Impeller, *revolutions per cu.ft.*
1½	100	20	7†	12 to 100	75
2	170	20	10†	16 to 170	75
3	400	20	15†	24 to 400	55
4	700	20	20†	40 to 700	15
6	1,600	20	30	80 to 1,600	15
8	2,800	20	50	144 to 2,800	3
10	4,400	20	75	224 to 4,400	3
12	6,400	20	100	320 to 6,400	1.5
16	12,400	20	150	400 to 12,400	0.5

* See note 3a (*re* Excessive Wear).
† See Sec. 2–4.

Sec. 2–3.2—External Bolts

All external bolts and washers shall be of non-ferrous material, or protective treated iron or steel. Nuts shall be of non-ferrous material and be designed for easy removal after having been long in service.

Sec. 2–3.3—Connections

3.3.1—*Connections for 1½- and 2-in. Meters*

Main case connections for 1½- and 2-in meters may be either spuds or flanges, as required.

3.3.1.1—*Spuds.* Spuds shall be tapped 1½ and 2 in., respectively, American Standard internal taper pipe thread (ASA B2.1–1942).

3.3.1.2—*Flanges.* Flanges shall be faced and drilled and shall be either of the round or oval type, as required. If of the round type, they shall conform to the American Standard cast-iron pipe flange, class 125 (ASA B16a–1939) for diameter, drilling and thickness. If of the oval type, the drilling shall be on the horizontal axis, the thickness shall be at least as great as required for round flanges and the diameter of the bolt circle shall be 4 in. for 1½-in. meters and 4½ in. for 2-in. meters. The companion flanges shall be made of cast iron, and shall be tapped 1½ and 2 in., respectively, American Standard internal taper pipe thread (ASA B2.1–1942). Companion flanges, gaskets, bolts, nuts and washers shall be provided.

3.3.2—*Connections for 3-, 4-, 6-, 8-, 10-, 12- and 16-in. Meters*

Main case connections shall be flanged. Flanges shall be of the round type, faced and drilled, and shall conform to the American Standard cast-iron pipe flange, class 125 (ASA B16a–1939) for diameter, drilling and thickness. Companion flanges shall be faced and drilled and they may be standard companion flanges, flange and bell, flange and spigot, or a combination of any. Standard companion flanges shall be tapped 3, 4, 6, 8, 10, 12 and 16 in., respectively, American Standard internal taper pipe thread (ASA B2.1–1942). Flange and bell and flange and spigot connections shall

TABLE 2

Current Meters

(1) Meter Size, *in.*	Meter Length, *in.*		(4) Tail Piece Length, *in.*	Maximum Indication of Initial Dial		Minimum Capacity of Register	
	(2) Minimum	(3) Maximum		(5) *cu.ft.*	(6) *gal.*	(7) *mil.cu.ft.*	(8) *mil.gal.*
1½	12¾	13	2⅞	10	100	10	100
2	15¼	18⅝	3	10	100	10	100
3	20	24		10	100	10	100
4	22	29¼		100	1,000	10	100
6	24	36¾		100	1,000	100	1,000
8	26¾	48¾		1,000	10,000	100	1,000
10	30	60		1,000	10,000	100	1,000
12	36	68		1,000	10,000	1,000	10,000
16	42	42		1,000	10,000	1,000	10,000

be of cast iron and conform to the American Standard cast-iron pit-cast pipe, class 150 (ASA A21.2–1939), *as far as the specifications apply.* Companion flanges, gaskets, bolts, nuts and washers shall be provided.

Sec. 2–3.4—Registers

Registers may be either "round-" or "straight-" reading, indicating in cubic feet or gallons.

3.4.1—*Round-Reading Registers*

The register pinion and spur gears shall be firmly fastened on their spindles, shall fully mesh with each other and run freely, and shall be so constructed that they cannot become unmeshed. The spindle bearings in the top and bottom register plates shall be bushed with hard vulcanized rubber or other non-metallic bushings. These bushings shall have sufficient depth to insure ample spindle bearing and sufficient clearance to allow the spindles to revolve freely; shall be fitted so they will not work loose; shall be removable; and shall be as nearly as possible non-warping, non-shrinking and non-expanding in heat. The register throughout, except for the dial and index hands, shall be plated or given other protective treatment, or shall be made of material as nearly non-corrosive as possible.

The maximum indication of the initial dial and the minimum capacity of the register, when indicating cubic feet, shall be as given in Table 2, Columns 5 and 7, and, when indicating gallons, as given in Columns 6 and 8.

All the index circles, including the initial circle, shall be subdivided into ten equal parts. All hands or pointers shall taper to a sharp point and shall be accurately set and securely held in place.

3.4.2—*Straight-Reading Registers*

The figures on the number wheels shall be large and distinct so that they can be read easily. The register lock and side gears shall be securely fastened to their number wheel discs and hubs. The tumbler pinions shall mesh accurately at the turnover points with the lock and side gears of the adjacent number wheels. Both main and pinion shafts shall be so secured in the register frame that they cannot get out of

position. The pinion shaft shall be so designed that there is no possibility of its bending and allowing the pinion to skip at the turnover point. All parts of the register shall be plated or given a protective treatment, or shall be made of material as nearly non-corrosive as possible.

The maximum indication of the digits appearing on the first number wheel and the minimum capacity of the register, when indicating cubic feet, shall be as given in Table 2, Columns 5 and 7, and, when indicating gallons, shall be as given in Columns 6 and 8.

There shall be a test index circle which shall be divided into ten equal parts. The hand or pointer shall taper to a sharp point and shall be accurately set and securely held in place.

Sec. 2–3.5—Register Boxes

Register boxes and lids shall be made of bronze composition or of the same material as the top case, with the name of the manufacturer cast on the lid in raised letters. The serial number of the meter shall be plainly stamped on the lid. If required, the serial number shall also be stamped on the case. The lid shall be recessed and shall lap over the box so that dirt will be prevented from accumulating on the glass. The glass shall be inserted from the inside and shall be securely held in place without the use of putty or pins. All register compartments shall be provided with a water escape hole $\frac{1}{8}$ in. in diameter. When the meter is equipped with a hood, the register box lid may be omitted.

Sec. 2–3.6—Intermediate Gear Trains

Intermediate gear trains may be mounted on the measuring chambers or in the upper main casings. Gear train frames, spindles, gears and pinions shall be made of durable non-ferrous material. Pinions and spur gears shall be firmly fastened, shall fully mesh with each other and shall run freely. The lower end-bearings for pinion and spur gear spindles that revolve shall be fitted with hard vulcanized rubber or other non-metallic bushings fastened in place so they will not fall or work out and they shall be easily removable. Gear trains may be of either the oil-enclosed or open type. If of the oil-enclosed type, the gear trains shall have a separate housing or shall form a housing with the main casings or measuring chamber and shall operate in a suitable lubricant.

Sec. 2–3.7—Measuring Chambers

The measuring chambers or cages for all meters shall be made of bronze or non-ferrous composition and shall be a self-contained unit firmly seated and easily detached and removed from the main case. Chambers with impellers that have revolving spindles shall have long, hard-rubber-bushed, removable bearings for such spindles. Chambers with impellers that revolve around a stationary stem shall contain a rigid, centrally located, stationary stem for suspending the impeller.

Sec. 2–3.8—Impellers

The measuring impellers, wheels or pistons for all meters shall be made of vulcanized hard rubber. The measuring impeller shall be mounted, or shall rotate, on phosphor-bronze or other suitable metal spindle and shall be supported by jewel, ball or other suitable bearings. Measuring impellers mounted on spindles shall revolve in hard-rubber-bushed bearings. The measuring impeller, together with its spindle, shall be as nearly as possible of the same specific gravity as water.

The number of impeller revolutions per cubic foot should not exceed the quantities given in Table 1, Column 6.

Sec. 2–3.9—Strainers

Meters may or may not be provided with strainers. Strainers, if provided, shall be rigid, shall be easily removed and shall have an effective straining area as large as practicable and at least double that of the meter main case inlet.

Sec. 2–3.10—Seal Wire Holes

Register box screws and inlet and outlet couplings shall be drilled for seal wire holes. All seal wire holes shall be not less than $\frac{3}{32}$ in. in diameter.

Section 2–4—Registration

The registration on the meter dial shall indicate the quantity recorded to be not less than 97 per cent nor more than 103 per cent of the water actually passed through the meter while it is being tested at any rate of flow within the limits specified in Table 1, Column 5, under "Normal Test Flow Limits." There shall be not less than 95 per cent of the actual flow recorded when a test is made at the rate of flow set forth in Table 1, Column 4, under "Minimum Test Flow."

Current meters in 1½-, 2-, 3- and 4-in. sizes are not recommended for use where minimum rates of flow less than 7, 10, 15 and 20 gpm., respectively, are likely to be encountered.

For 1½- and 2-in. sizes, displacement meters should be used.

For 3- and 4-in. sizes, compound or displacement meters should be used.

Section 2–5—Pressure Test

Meters shall be guaranteed to operate under a working pressure of 150 psi. without leakage or damage to any part.

Section 2–6—Workmanship and Materials

Meters shall be guaranteed against defects in materials and workmanship for a period of one year from date of shipment. Parts to replace those in which a defect has developed within such period shall be supplied without charge, piece for piece, upon the return of such defective parts to the manufacturer thereof or upon proper proof of such defect.

Section 2–7—Rejected Meters

The manufacturer shall, at his own expense, replace or satisfactorily readjust all meters rejected for failure to comply with these specifications.

NOTES

These notes are not part of the specifications. They are given only as information concerning the testing and care of meters and important materials used in meter construction. They are not intended to limit in any way the future development of better materials for general use or the use of special metals with specific waters which may require materials of different composition to give service equal to that recorded in normal practice.

(1) *Tests*

Capacity tests are those which test the design of the meter. When a meter of a given design has once been tested for capacity it should not be necessary to test this type of meter again unless a change has been made in the design.

Registration tests are those which test the assembly and workmanship of the meter. Each meter should be tested for registration, as there is no certainty that, because one meter of a given design is within certain limits of accuracy, all meters of this design will necessarily give similar results. The register furnished with each meter should be used by both the manufacturer and the purchaser in making registration tests.

All meters should be tested for accuracy of registration within, and as near as practicable to, the low and high rates given under "Normal Test Flow Limits," and occasionally additional tests should be made at one or more intermediate points. A test at the "Minimum Test Flow" should be made on all meters.

A pressure test should be made on each size of meter of a particular design furnished. This pressure is to be 150 psi., and may be obtained by the use of a hand pump or any method available. The meter should be tested for accuracy before and after it has been tested by static pressure to determine whether there has been any distortion that would affect the registration. It is unnecessary to make more than one pressure test on each size of a given design if satisfactory results are obtained. A working pressure test is preferable to a static pressure test.

If the purchaser has no testing equipment, a certificate should be furnished by the manufacturer showing that each meter has been tested for accuracy of registration and that it complies with the specifications and that the size and design comply with the capacity requirements.

(2) *Testing Equipment*

The minimum test equipment is as follows:

(a) A valve on the supply line which would permit the starting and stopping of the flow without appreciable loss of time.

(b) A valve or other suitable device on the discharge line which can provide the rate of flow desired.

(c) Pressure gages on supply and discharge pipes, so that any change in pressure which would affect the rate of flow can be detected. The discharge pipe must be under sufficient head to guarantee a pressure on the outlet of the meter.

(d) A measuring device of either the volumetric or weighing type. The accuracy of the determination of the amount of water discharged should be such as to bring the limit of error within 0.25 per cent. The amount of water passed should be sufficient to cause at least one revolution of the pointer on the initial dial except for the test at the "Minimum Test Flow" rate. The amount passed as the "Minimum Test Flow" rate should be of sufficient quantity to secure a true indication of the accuracy.

(e) Two piezometer rings of exactly the same diameter for capacity tests. The piezometer rings must be free from any burrs where the holes are drilled through the wall of the ring, and not fewer than four holes shall be provided, drilled in pairs on diameters at right angles to each other. The inlet ring shall be set close to the meter at a distance of eight diameters or more below the nearest upstream stop valve or fitting, and the outlet ring shall be placed at a distance of between eight and ten diameters from the outlet of the meter. The diameter of the rings, the inlet and the outlet pipes shall be the same as the size of the meter to be tested. The rings are to be connected to a mercury U-tube, equipped with an accurate adjustable scale for measuring the difference in mercury level, by rubber or metallic tubing. Provision is to be made for the complete removal of air from the U-tube and tubing connected therewith, and the installation is to be such that air will rise to the air outlets. Where relatively high flows are to be measured, it is necessary to read both sides of the mercury column simultaneously in order to compensate for irregu-

larities in the diameter of the glass U-tube, and to avoid errors due to fluctuations.

Suitable pressure gages may also be used.

(3) *Care of Meters*

In a current meter the motion of the impeller is transmitted by a system of gearing to the register where the flow is recorded in convenient units of measure, as cubic feet or gallons. The gearing serves to translate the motion of the impeller into the unit of measure indicated by the register. The register is at all times a measure of the number of revolutions of the measuring impeller in terms of cubic feet or gallons. It records a true measure of flow only when the meter has been properly calibrated by gear adjustment, and after proper calibration will continue to register correctly only as long as the impeller continues to make the proper number of cycles for each unit of quantity passed through the meter. If, after calibration, any condition should develop whereby the impeller is compelled to make less than the proper number of cycles per unit of quantity passed through it, the meter will under-register. If the impeller is compelled to make more than the proper number of cycles, the meter will over-register. The proper number of cycles is the number made at the time the meter is calibrated. Under ordinary working conditions, there are a number of factors that may cause under- or over-registration after comparatively short intervals. The more important of these factors which should be guarded against to secure proper registration are:

(a) *Excessive Wear.* Excessive wear of the moving parts of the meter may be caused by improper setting, by over-speeding, or, in general, by the selection of a meter too small for the work required. The effect of excessive wear of the impeller or measuring chamber is slippage and under-registration. Excessive wear of the intermediate gear train may cause binding of the gears or gear slippage. In any case, if the meter is not stopped entirely, under-registration will result. To avoid excessive wear, meters should be set in a horizontal position and should not be run at destructive speeds. The capacity of the meters given in the specifications represents the maximum rates of flow at which water should be passed through meters for short periods of time or the peak loads which should come upon meters only at long intervals. These rates would be destructive under continuous service. For continuous 24-hour service meters of the current type should not be operated on flows greater than one-third of the capacity of the meter.

(b) *Temperatures.* High temperatures cause expansion of the rubber impellers, which tends to create unusual friction or to bind the impeller in its chamber. The effect is slippage and under-registration, or failure of the meter. Low temperatures have no noticeable effect on the working parts of the meter. Freezing will stop the meter and possibly damage it.

Cold water meters are not affected by temperatures up to about 80°F. In warm climates, where the temperature of the water is likely to go above 80°F., meters with clearances slightly larger than ordinary should be used, and accuracies indicated in specifications must be modified accordingly.

To avoid troubles caused by temperature, meters should be set at locations where they will be protected from heat and frost. At locations where hot water from heating systems may be forced back through the meter, a check and relief valve should be installed on the outlet side of the meter.

(c) *Corrosion.* All the metals used in the construction of a meter are affected by the corrosive action of water. The action is very slow with most potable waters. The result is that parts of the meter are weakened, particularly the teeth of the open intermediate gears, and, with meters that are idle for long intervals, there is a tendency toward binding. Tuberculation of the outer case in meters of the current type may change the normal direction of flow and cause over-registration.

(d) *Material in Suspension.* Foreign material carried in suspension may be deposited and accumulations of deposit always tend to cause over-registration, as any conditions tending to change the velocity of flow, after the meter has been calibrated, will cause over-registration. Such over-registration is not limited.

Meters provided with strainers will retain the larger particles of material in suspension, but the strainer will soon become clogged if the water is not kept reasonably free of suspended matter. Sand is especially destructive and care should be exercised to keep sand from reaching the supply pipes.

The finer particles of suspended material cannot be prevented from reaching the meter

and troubles from this source can be avoided only by cleaning the meter periodically, the interval between cleanings depending upon the quality of the water.

(e) *Periodic Tests.* Meters properly selected as to size and type will give satisfactory service over a long period of time without attention only when operated under ideal conditions. Under ordinary conditions meters must be given some care if they are to function properly. In most cases it is impossible to ascertain, without actual test, whether a meter which has been in service is registering within the required degree of accuracy. Consequently, to insure reliable meter measurements, it is essential that all meters be subjected to periodic tests. The interval between tests and the method of conducting them must be governed largely by local conditions. Under *average* conditions the following intervals between tests should not be exceeded:

Meter Size, *in.*	Years Between Tests
1½	4
2	4
3	3
4	2
6	1
8	1
10	1
12	1
16	1

Many state regulatory commissions specify the intervals between tests on both a time and quantity basis.

Meters of the current type used for measuring unfiltered surface waters should be cleaned about once a year, in order that they may be kept in good working condition. When filtered or exceptionally clean water is used, the interval between cleanings may be longer.

Best results will be obtained from current meters if they are calibrated in place, since the accuracy of these meters is affected by changes in the distribution of velocities through the meter. A meter of this type, calibrated in a testing machine under conditions where there is a bend near the inlet side of the meter, may register incorrectly from the start if installed under conditions where there is a straight run of pipe in the inlet side. Any other condition tending to change the distribution of velocities as existent at the time of calibration will have the same effect. If calibrated on premises this source of error is minimized.

For 3-in. and larger meters the installation of a test tee in the outlet piping makes testing easier and reduces the cost of testing.

(4) *Bronze.* A bronze which is satisfactory for most waters is that of specifications B62–36 of the American Society for Testing Materials or No. 2 Federal Specifications QQ–B–691a for an alloy of copper, tin, lead and zinc, known commercially as composition metal, 85–5–5–5, ounce metal, red brass or hydraulic bronze.

(5) *Rubber.* A satisfactory rubber for impellers and bushings should, among other items, have a specific gravity under 1.2, a minimum tensile strength of 6,500 psi., a maximum elongation of 5 per cent, a hardness (scleroscope test) of not less than 67, a free sulfur content of 3 per cent or less, a free ash content of not more than 3 per cent and a uniformity of cure and physical characteristics.

American Water Works Association

Tentative

STANDARD SPECIFICATIONS

for

COLD WATER METERS—COMPOUND TYPE

These "Tentative Standard Specifications for Cold Water Meters—Compound Type" are based upon the best known experience and are intended for use under normal conditions. They are not designed for unqualified use under all conditions and the advisability of use of the material herein specified for any installation must be subjected to review by the engineer responsible for the installation in the particular locality concerned.

Approved as Tentative by the Board of Directors of the A.W.W.A. on January 14, 1946

Copyrighted as Part of the April 1946 Journal of the American Water Works Association

First Printing, April 1946

AMERICAN WATER WORKS ASSOCIATION
Incorporated
500 Fifth Avenue, New York 18, N.Y.

Prepared by

Water Works Practice Committee 7M

Personnel

SAMUEL F. NEWKIRK JR., *Chairman*

EDWARD V. BUCHANAN
JAMES G. CARNS JR.
A. P. KURANZ
H. W. NIEMEYER
H. V. PEDERSEN
GEORGE READ
GEORGE J. ROHAN
GEORGE C. SOPP
L. S. VANCE
W. VICTOR WEIR

Table of Contents

General—Section 3–1

SECTION

Scope 3–1.1
Kind and Type 3–1.2

Capacity, Size and Length—Section 3–2

Capacity 3–2.1
Size 3–2.2
Length 3–2.3

Design—Section 3–3

Cases 3–3.1
External Bolts 3–3.2
Connections 3–3.3
Registers 3–3.4
Register Boxes 3–3.5
Intermediate Gear Trains 3–3.6
Measuring Chambers 3–3.7
Pistons 3–3.8
Impellers 3–3.9
Automatic Valves 3–3.10
Strainers 3–3.11
Seal Wire Holes 3–3.12

Registration—Section 3–4

Pressure Test—Section 3–5

Workmanship and Materials—Section 3–6

Rejected Meters—Section 3–7

NOTES

Tests 1
Testing Equipment 2
Care of Meters 3
Bronze 4
Rubber 5

Tentative

Standard Specifications for Cold Water Meters

Compound Type

Section 3–1—General

Sec. 3–1.1—Scope

These specifications embrace the various types and classes of cold water compound meters for water works consumer service and cover the materials and workmanship employed in their fabrication.

Sec. 3–1.2—Kind and Type

The kinds of meters covered are service meters of the compound type, which consist of the combination of a main meter of the current or displacement type for measuring large flows and a small displacement type meter for measuring small flows, in conjunction with an automatic valve mechanism.

Section 3–2—Capacity, Size and Length

Sec. 3–2.1—Capacity

Capacity or delivery classification shall be the quantity given in Table 1, Column 2, and is determined by the quantity delivered at the permissible maximum loss of head.

Meters shall have a loss of head not exceeding 20 psi., when the rate of flow is that given in Table 1, Column 2.

Sec. 3–2.2—Size

The size of the meter given in Table 1, Column 1, shall be in terms of the nominal size of opening in the inlet and outlet spuds or flanges of the meter.

Sec. 3–2.3—Length

The minimum and maximum overall lengths of the meter, face to face of spuds or flanges, are given in Table 2, Columns 2 and 3. A filler piece can be inserted to increase the length of the shorter meter if required, but the meter itself must not be shorter than the minimum length given in the table.

Section 3–3—Design

Sec. 3–3.1—Cases

The outer cases shall be of bronze composition or of cast iron protected by a non-corrosive treatment. Castings shall not be repaired, plugged, brazed or "burned in."

TABLE 1

Compound Meters

(1) Meter Size, *in.*	(2) Safe Maximum Operating Capacity,* *gpm.*	(3) Maximum Loss of Head, *psi.*	(4) Minimum Test Flow, *gpm.*	(5) Normal Test Flow Limits, *gpm.*
1½	100	20	½	2 to 100
2	160	20	½	2 to 160
3	320	20	1	4 to 320
4	500	20	1½	6 to 500
6	1,000	20	3	10 to 1,000
8	1,600	20	4	16 to 1,600
10	2,300	20	8	32 to 2,300
12	3,100	20	14	32 to 3,100

* See note 3a (*re* Excessive Wear).

All meters shall have cast on them, in raised characters, the size and model. The direction of the flow through the meter shall be properly indicated. Meters composed of a combination of independent units in separate housings shall have this information cast on each unit. Meters shall be designed for easy removal of all interior parts without disturbing the connections to the pipeline.

Sec. 3–3.2—External Bolts

All external bolts and washers shall be of non-ferrous material, or protective treated iron or steel. Nuts shall be of non-ferrous material and be designed for easy removal after having been long in service.

Sec. 3–3.3—Connections

3.3.1—*Connections for 1½- and 2-in. Meters*

Main case connections for 1½- and 2-in. meters may be either spuds or flanges, as required.

3.3.1.1—*Spuds.* Spuds shall be tapped 1½ and 2 in., respectively, American Standard internal taper pipe thread (ASA B2.1–1942).

3.3.1.2—*Flanges.* Flanges shall be faced and drilled and shall be either of the round or oval type, as required. If of the round type, they shall conform to the American Standard cast-iron pipe flange, class 125 (ASA B16a–1939) for diameter, drilling and thickness. If of the oval type, the drilling shall be on the horizontal axis, the thickness shall be at least as great as required for round flanges and the diameter of the bolt circle shall be 4 in. for 1½-in. meters and 4½ in. for 2-in. meters. The companion flanges shall be made of cast iron and shall be tapped 1½ and 2 in., respectively, American Standard internal taper pipe thread (ASA B2.1–1942).

3.3.2—*Connections for 3-, 4-, 6-, 8-, 10- and 12-in. Meters*

Main case connections shall be flanged. Flanges shall be of the round type, faced and drilled, and shall conform to the American Standard cast-iron pipe flange, class 125 (ASA B16a–1939) for diameter, drilling and thickness. Companion flanges shall be faced and drilled and they may be standard companion flanges, flange and bell, flange and spigot or a combination of any. Standard companion flanges shall be tapped 3, 4, 6, 8, 10 and 12 in., respectively, American Standard internal taper pipe thread (ASA B2.1–1942). Flange and bell, and flange and spigot connections shall be of cast iron and shall conform to the American Standard cast-iron pit-cast pipe, class 150 (ASA A21.2–1939), *as far as the specifications apply.* Companion flanges, gaskets, bolts, nuts and washers shall be provided.

Sec. 3–3.4—Registers

Registers may be either "round-" or "straight-" reading, indicating in cubic feet or gallons.

TABLE 2

Compound Meters—Main Unit

(1) Meter Size, *in.*	Meter Length, *in.* (2) Minimum	(3) Maximum	(4) Tail Piece Length, *in.*	Maximum Indication of Initial Dial (5) *cu.ft.*	(6) *gal.*	Minimum Capacity of Register (7) *mil.cu.ft.*	(8) *mil.gal.*	(9) Speeds, *revolutions per cu.ft.*
1½	18⅝	20⅞	2⅞	10	100	10	100	75
2	13	28¾	3	10	100	10	100	75
3	17	37½		10	100	10	100	55
4	20	39½		100	1,000	10	100	15
6	24	51 7/16		100	1,000	100	1,000	15
8	30	60⅝		1,000	10,000	100	1,000	3
10	36	72¾		1,000	10,000	100	1,000	3
12	64½	77		1,000	10,000	1,000	10,000	1.5

3.4.1—*Round-Reading Registers*

The register pinion and spur gears shall be firmly fastened on their spindles, shall fully mesh with each other and run freely, and shall be so constructed that they cannot become unmeshed. The spindle bearings in the top and bottom register plates shall be bushed with hard vulcanized rubber or other non-metallic bushings. These bushings shall have sufficient depth to insure ample spindle bearing and sufficient clearance to allow the spindles to revolve freely; shall be fitted so they will not work loose; shall be removable; and shall be as nearly as possible non-warping, non-shrinking and non-expanding in heat. The register throughout, except for the dial and index hands, shall be plated or given other protective treatment, or shall be made of material as nearly non-corrosive as possible.

The maximum indication of the initial dial and the minimum capacity of the register of the main meter, when indicating cubic feet, shall be as given in Table 2, Columns 5 and 7, and, when indicating gallons, as given in Columns 6 and 8. The maximum indication of the initial dial and the minimum capacity of the register of the bypass meter, when indicating cubic feet, shall be as given in Table 3, Columns 2 and 4, and, when indicating gallons, as given in Columns 3 and 5.

All the index circles, including the initial circle, shall be subdivided into ten equal parts. All hands or pointers shall taper to a sharp point and shall be accurately set and securely held in place.

3.4.2—*Straight-Reading Registers*

The figures on the number wheels shall be large and distinct so that they can be read easily. The register lock and side gears shall be securely fastened to their number wheel discs and hubs. The tumbler pinions shall mesh accurately at the turn-over points with the lock and side gears of the adjacent number wheels. Both main and pinion shafts shall be so secured in the register frame that they cannot get out of position. The pinion shaft shall be so designed that there is no possibility of its bending and allowing the pinion to skip at the turn-over point. All parts of the register shall be plated or given a protective treatment, or shall be made of material as nearly non-corrosive as possible.

The maximum indication of the digits appearing on the first number wheel and the minimum capacity of the register of the main meter, when indicating cubic feet, shall be as given in Table 2, Columns 5 and 7, and, when indicating gallons, shall be as given in Columns 6 and 8. The maximum indication of the digits appearing on the first number wheel and the minimum capacity of the register of the bypass meter, when indicating cubic feet, shall be as given in Table 3, Columns 2 and 4, and, when indicating gallons, as given in Columns 3 and 5.

There shall be a test index circle which shall be divided into ten equal parts. The hand or pointer shall taper to a sharp point and shall be accurately set and securely held in place.

Sec. 3–3.5—Register Boxes

Register boxes and lids shall be made of bronze composition or shall be of the same material as the top case, with the name of manufacturer cast on the lids in raised letters. The serial number of the meter shall be plainly stamped on the lids of both the main and bypass meters. If required, the serial number shall also be stamped on the cases. The lids shall be recessed and shall lap over the box so that dirt will be prevented from accumulating on the glass. The glass shall be inserted from the inside and shall be securely held in place without the use of putty or pins. All register compartments shall be provided with a water escape hole $\frac{1}{8}$ in. in diameter. When the meter is equipped with hoods the register box lids may be omitted.

Sec. 3–3.6—Intermediate Gear Trains

Intermediate gear trains may be mounted on the measuring chambers or in the upper main casings. Gear train frames, spindles, gears and pinions shall be made of durable non-ferrous material. Pinions and spur gears shall be firmly fastened, shall fully mesh with each other and shall run freely. The lower end-bearings for pinion and spur gear spindles that revolve shall be fitted with hard vulcanized rubber or other non-metallic bushings fastened in place so they will not fall or work out and they shall be easily removable. Gear trains may be of either the oil-enclosed or open type. If of the oil-enclosed type, the gear trains shall have a separate housing or shall form a housing with the main casings or measuring chamber and shall operate in a suitable lubricant.

Sec. 3–3.7—Measuring Chambers

3.7.1—*Displacement*

The measuring chambers for displacement type meters shall be made of bronze or non-ferrous composition and shall not be cast as part of the outer casings. They shall be machined carefully and secured in position in the outer casings so that any slight distortion of the casings which might occur under 150-lb. pressure will not affect the sensitiveness of the meters.

3.7.2—*Current*

The measuring chambers or cages for current type meters shall be made of bronze or non-ferrous composition and shall be self-contained units firmly seated and easily detached and removed from the main case. Chambers with impellers that have revolving spindles shall have long, hard rubber, bushed, removable bearings for such spindles. Chambers with impellers that revolve around a stationary stem shall contain a rigid, centrally located, stationary stem for suspending the impeller.

Sec. 3–3.8—Pistons

The measuring pistons of the displacement type meters shall be made of vulcanized hard rubber, shall be smoothly machined, shall be fitted accurately in their measuring chambers and shall operate smoothly and freely. The plates of disc pistons, whether flat or conical, shall have metal reinforcements or shall be equipped with thrust rollers. Disc pistons may be in one piece or the piston plates may be in one piece and the piston balls in two pieces. The piston spindles or shafts shall be securely fastened in the pistons.

The piston reciprocations, rotations, oscillations or nutations per cubic foot shall not exceed the quantities given in Table 3, Column 6.

Sec. 3–3.9—Impellers

Measuring impellers, wheels or pistons of the current type meters shall be made of vulcanized hard rubber. The measuring impeller shall be mounted, or shall rotate, on phosphor-bronze or other suitable metal spindle and shall be supported by jewel, ball or other suitable bearings. Measuring impellers mounted on spindles shall revolve in hard-rubber-bushed bearings. The measuring impeller, together with its spindle, shall be as nearly as possible of the same specific gravity as water.

The number of impeller revolutions per cubic foot should not exceed the quantities given in Table 2, Column 9.

Sec. 3–3.10—Automatic Valves

Automatic valves may be of the compound swing or lever type, the vertical lifting type or a type suitable for such purpose.

TABLE 3

Compound Meters—Bypass Unit

(1) Meter Size, *in.*	Maximum Indication of Initial Dial		Minimum Capacity of Register		(6) Speeds, *revolutions per cu.ft.*
	(2) *cu.ft.*	(3) *gal.*	(4) *mil. cu.ft.*	(5) *mil. gal.*	
$\frac{5}{8}$	1	10	0.1	1	435
$\frac{3}{4}$	1	10	1	10	250
1	10	100	1	10	115
$1\frac{1}{2}$	10	100	10	100	50
2	10	100	10	100	30
3	10	100	10	100	15

Sec. 3–3.11—Strainers

Meters may or may not be provided with strainers. Strainers, if provided, shall be rigid, shall be easily removed and shall have an effective straining area as large as practicable and at least double that of the meter main case inlet.

Sec. 3–3.12—Seal Wire Holes

Register box screws and inlet and outlet couplings shall be drilled for seal wire holes. All seal wire holes shall not be less than $\frac{3}{32}$ in. in diameter.

Section 3–4—Registration

The registration on the meter dials shall indicate the quantity recorded to be not less than 97 per cent nor more than 103 per cent of the water actually passed through the meter while it is being tested at any rate of flow within the limits specified in Table 1, Column 5, under "Normal Test Flow Limits," except in the registration of flows within the "change-over" from bypass meter to main meter. The registration at these rates of flow shall not be less than 85 per cent. The difference in the rate of flow at the beginning and

at the end of the "change-over" shall not exceed the figures given in the following table.

Size, in.	Rate of Flow, gpm.
1½	20
2	30
3	60
4	100
6	200
8	320
10	460
12	620

The beginning of the "change-over" is when the accuracy of registration falls below 97 per cent, due to the operation of the automatic valve mechanism, and the end of the "change-over" is when the accuracy of registration again reaches 97 per cent.

There shall be not less than 95 per cent of actual flow recorded when a test is made at the rate of flow set forth in Table 1, Column 4, under "Minimum Test Flow."

Section 3–5—Pressure Test

Meters shall be guaranteed to operate under a working pressure of 150 psi. without leakage or damage to any part.

Section 3–6—Workmanship and Materials

Meters shall be guaranteed against defects in materials and workmanship for a period of one year from date of shipment. Parts to replace those in which a defect has developed within such period shall be supplied without charge, piece for piece, upon the return of such defective parts to the manufacturer thereof or upon proper proof of such defect.

Section 3–7—Rejected Meters

The manufacturer shall, at his own expense, replace or satisfactorily readjust all meters rejected for failure to comply with these specifications.

NOTES

These notes are not part of the specifications. They are given only as information concerning the testing and care of meters and important materials used in meter construction. They are not intended to limit in any way the future development of better materials for general use or the use of special metals with specific waters which may require materials of different composition to give service equal to that recorded in normal practice.

(1) *Tests*

Capacity tests are those which test the design of the meter. When a meter of a given design has once been tested for capacity it should not be necessary to test this type of meter again unless a change has been made in the design.

Registration tests are those which test the assembly and workmanship of the meter. Each meter should be tested for registration, as there is no certainty that, because one meter of a given design is within certain limits of accuracy, all meters of this design will necessarily give similar results. The register furnished with each meter should be used by both the manufacturer and the purchaser in making registration tests.

All meters should be tested for accuracy of registration within, and as near as practicable to, the low and high rates given under "Normal Test Flow Limits," and occasionally additional tests should be made at one or more intermediate points. A test at the "Minimum Test Flow" should be made on all meters.

A pressure test should be made on each size of meter of a particular design furnished. This pressure is to be 150 psi., and may be obtained by the use of a hand pump or any method available. The meter should be tested for accuracy before and after it has been tested by static pressure to determine whether there has been any distortion that would affect the registration. It is unnecessary to make more than one pressure test on each size of a given design if satisfactory results are obtained. A working pressure test is preferable to a static pressure test.

If the purchaser has no testing equipment, a certificate should be furnished by the manufacturer showing that each meter has been tested for accuracy of registration and that it complies with the specifications and that the size and design comply with the capacity requirements.

(2) *Testing Equipment*

The minimum test equipment is as follows:

(a) A valve on the supply line which would permit the starting and stopping of the flow without appreciable loss of time.

(b) A valve or other suitable device on the discharge line which can provide the rate of flow desired.

(c) Pressure gages on supply and discharge pipes, so that any change in pressure which would affect the rate of flow can be detected. The discharge pipe must be under sufficient head to guarantee a pressure on the outlet of the meter.

(d) A measuring device of either the volumetric or weighing type. The accuracy of the determination of the amount of water discharged should be such as to bring the limit of error within 0.25 per cent. The amount of water passed should be sufficient to cause at least one revolution of the pointer on the initial dial except for the test at the "Minimum Test Flow" rate. The amount passed at the "Minimum Test Flow" rate should be of sufficient quantity to secure a true indication of the accuracy.

(e) Two piezometer rings of exactly the same diameter for capacity tests. The piezometer rings must be free from any burrs where the holes are drilled through the wall of the ring, and not fewer than four holes shall be provided, drilled in pairs on diameters at right angles to each other. The inlet ring shall be set close to the meter at a distance of eight diameters or more below the nearest upstream stop valve or fitting, and the outlet ring shall be placed at a distance of between eight and ten diameters from the outlet of the meter. The diameter of the rings, the inlet and the outlet pipes shall be the same as the size of the meter to be tested. The rings are to be connected to a mercury U-tube, equipped with an accurate adjustable scale for measuring the difference in mercury level, by rubber or metallic tubing. Provision is to be made for the complete removal of air from the U-tube and tubing connected therewith, and the installation is to be such that air will rise to the air outlets. Where relatively high flows are to be measured, it is necessary to read both sides of the mercury column simultaneously in order to compensate for irregularities in the diameter of the glass U-tube and to avoid errors due to fluctuations.

Suitable pressure gages may also be used.

(3) *Care of Meters*

In a compound meter the motions of the pistons and impellers are transmitted by a system of gearing to the register where the flow is recorded in convenient units of measure, as cubic feet or gallons. The gearing serves to translate the motion of the pistons and impellers into the unit of measure indicated by the registers. The register is at all times a measure of the number of revolutions of the pistons or measuring impellers in terms of cubic feet or gallons. It records a true measure of flow only when the meter has been properly calibrated by gear adjustment, and after proper calibration will continue to register correctly only as long as the piston and impeller continue to make the proper number of cycles for each unit of quantity passed through the meter. If, after calibration, any condition should develop whereby the pistons or impellers are compelled to make less than the proper number of cycles per unit of quantity passed through it, the meter will under-register. If the pistons or impellers are compelled to make more than the proper number of cycles, the meter will over-register. The proper number of cycles is the number made at the time the meter is calibrated. Under ordinary working conditions, there are a number of factors that may cause under- or over-registration after comparatively short intervals. The more important of these factors which

should be guarded against to secure proper registration are:

(a) *Excessive Wear.* Excessive wear of the moving parts of the meter may be caused by improper setting, by over-speeding, or, in general, by the selection of a meter too small for the work required. The effect of excessive wear of the pistons, impellers or measuring chambers is slippage and under-registration. Excessive wear of the intermediate gear trains may cause binding of the gears or gear slippage. In any case, if the meter is not stopped entirely, under-registration will result. To avoid excessive wear, meters should be set in a horizontal position and should not be run at destructive speeds. The capacity of the meters given in the specifications represents the maximum rates of flow at which water should be passed through meters for short periods of time or the peak loads which should come upon meters only at long intervals. These rates would be destructive under continuous service. For continuous 24-hour service meters of the compound type should not be operated on flows greater than one-third of the capacity of the meter. If a compound meter is to be used for continuous service at a more or less uniform rate of flow, care should be taken to select a size of meter in which the "change-over" point is lower than the flow which is usually to be measured.

(b) *Temperatures.* High temperatures cause expansion of the rubber pistons and impellers, which tends to create unusual friction or to bind the piston or impeller in its chamber. The effect is slippage and under-registration, or failure of the meter. Low temperatures have no noticeable effect on the working parts of the meter. Freezing will stop the meter and possibly damage it.

Cold water meters are not affected by temperatures up to about 80°F. In warm climates, where the temperature of the water is likely to go above 80°F., meters with clearances slightly larger than ordinary should be used, and accuracies indicated in the specifications must be modified accordingly.

To avoid troubles caused by temperature, meters should be set at locations where they will be protected from heat and frost. At locations where the hot water from heating systems may be forced back through the meter, a check and relief valve should be installed on the outlet side of the meter.

(c) *Corrosion.* All the metals used in the construction of a meter are affected by the corrosive action of water. The action is very slow with most potable waters. The result is that parts of the meter are weakened, particularly the teeth of the open intermediate gears, and, with meters that are idle for long intervals, there is a tendency toward binding. Tuberculation of the outer case in meters of the current type may change the normal direction of flow and cause over-registration.

(d) *Material in Suspension.* Foreign material carried in suspension has a tendency to fill the space between the piston and measuring chamber and cause over-registration of displacement meters. Such over-registration, however, is limited and cannot generally exceed 3 per cent.

Accumulations of deposit always tend to cause over-registration of current meters, as any conditions tending to change the velocity of flow, after the meter has been calibrated, will cause over-registration. Such over-registration is not limited.

Meters provided with strainers will retain the larger particles of material in suspension, but the strainer will soon become clogged if the water is not kept reasonably free of suspended matter. Sand is especially destructive and care should be exercised to keep sand from reaching the supply pipes.

The finer particles of suspended material cannot be prevented from reaching the meter and troubles from this source can be avoided only by cleaning the meter periodically, the interval between cleanings depending upon the quality of the water.

(e) *Periodic Tests.* Meters properly selected as to size and type will give satisfactory service over a long period of time without attention only when operated under ideal conditions. Under ordinary conditions meters must be given some care if they are to function properly. In most cases it is impossible to ascertain, without actual test, whether a meter which has been in service is registering within the required degree of accuracy. Consequently, to insure reliable meter measurements, it is essential that all meters be subjected to periodic tests. The interval between tests and the method of conducting them must be governed largely by local conditions. Under *average* conditions the following intervals between tests should not be exceeded:

Meter Size, *in.*	Years Between Tests
1½	4
2	4
3	3
4	2
6	1
8	1
10	1
12	1

Many state regulatory commissions specify the intervals between tests on both a time and quantity basis.

Meters of the compound type used for measuring unfiltered surface waters should be cleaned about once a year in order that they may be kept in good working condition. When filtered or exceptionally clean water is used, the intervals between cleanings may be longer.

Best results will be obtained from compound meters if they are calibrated in place, since the accuracy of these meters is affected by changes in the distribution of velocities through the meter. A meter of this type, calibrated in a testing machine under conditions where there is a bend near the inlet side of the meter, may register incorrectly from the start if installed under conditions where there is a straight run of pipe in the inlet side. Any other condition tending to change the distribution of velocities as existent at the time of calibration will have the same effect. If calibrated on premises this source of error is minimized.

For 3-in. and larger meters the installation of a test tee in the outlet piping makes testing easier and reduces the cost of testing.

(4) *Bronze.* A bronze which is satisfactory for most waters is that of specifications B62–36 of the American Society for Testing Materials or No. 2 Federal Specifications QQ–B–691a for an alloy of copper, tin, lead and zinc, known commercially as composition metal, 85–5–5–5, ounce metal, red brass or hydraulic bronze.

(5) *Rubber.* A satisfactory rubber for pistons, measuring impellers and bushings should, among other items, have a specific gravity under 1.2, a minimum tensile strength of 6,500 psi., a maximum elongation of 5 per cent, a hardness (scleroscope test) of not less than 67, a free sulfur content of 3 per cent or less, a free ash content of not more than 3 per cent and a uniformity of cure and physical characteristics.

West Palm Beach, Florida—Survival and Retirement Experience With Water Works Facilities

As of December 31, 1940

PALM BEACH and West Palm Beach, Fla., are supplied with water by the privately owned and operated plant of the West Palm Beach Water Company. The two communities are located on the Atlantic shore of Florida, separated by Lake Worth, an arm of the ocean about ½ mi. wide. West Palm Beach has a permanent population of about 40,000 which is increased to about 50,000 during the winter months. It is predominantly a residential city but there are a number of small industries and it is the commercial and shipping center for the surrounding agricultural area. Palm Beach, located on the ocean, is a typical resort community, with a summer population of 5,000 and a winter population of about 20,000. The total population served ranges from 45,000 in the summer months to some 70,000 in the winter season.

As of the date of the study about 8,400 customers were attached to the distribution system, which consists of about 200 mi. of main and 822 fire hydrants.

Development of the Existing System

The initial water supply installation was made in 1894 by the Florida East Coast Hotel Company to supply water to the newly built Royal Poinciana Hotel in Palm Beach. The installation consisted of a pump on the shore of Clear Lake, a fresh water lake located about a mile west of Lake Worth and an 8-in. transmission main to Palm Beach. The water supplied was untreated, very soft, rather highly corrosive and contained considerable organic color.

Later, the area between Clear Lake and Lake Worth was subdivided and became West Palm Beach. The resulting settlement was served from the hotel company's supply as was also the small colony which developed in Palm Beach. In 1901 a franchise was granted by the town of West Palm Beach but the water system at that time had only about 200 customers. In 1909 the hotel company sold the system to the West Palm Beach Water Company. It was not until after 1920 that the area showed a substantial growth.

The first filters, rated at 3-mgd. capacity, were installed in 1919–20. An additional 3-mgd. extension was added in 1925. The growth after 1924 dictated the construction of more substantial supply and distribution works. The present filtration plant was completed in 1927 and, at the same time, electrically operated pumps were installed. The existing filtration plant is rated at 16 mgd. Treatment consists of aeration, sedimentation, filtration and chlorination, with Clear Lake remaining as the source.

Elevated storage is provided by a 2-mil.gal. standpipe located in West Palm Beach about 3½ mi. south of the pumping station. At the northerly end of Palm Beach there is a 1-mil.gal. ground storage reservoir which supply is pumped automatically into the system when required.

West Palm Beach and Palm Beach are connected by three subaqueous water crossings of 12-, 20- and 24-in. pipe.

Basis of Study

The information from which the data used in the study were secured was, for the early years, determined in an appraisal of the property made in 1928. Since 1925 the records of installation and retirement of pipe are complete.

The information on the installation of services, prior to 1925, was secured from existing records and data. Retirements of services prior to 1929 are incomplete and are not incorporated in this study.

Mortality Survival Study

Mortality survival studies were made of mains and services. Table 1 is a summary of the pipe installed, retired and the amount still in service, as well as other pertinent data. Table 2 is a similar summary of services. Figures 1 and 2 show the developed mortality survival curves of the respective facilities.

A summary of the principal items of Class B facilities is included hereafter.

SUMMARY OF CLASS B FACILITIES

WEST PALM BEACH, FLORIDA

Pumping Equipment

No.	Type	Power	Capacity *mgd.*	Year Installed	Year Retired	Salvage Value	Cost	Cause of Retirement
1	Reciprocating High-Lift (Snow) *	Steam Engine		1902	1926	$200	$ 4,500	OIS
1	Reciprocating High-Lift (Platt)			1912	1926	200	5,500	IS
1	Reciprocating High-Lift (Laidlaw)		1.5 mgd.	1912	1930	200	11,487	IS
1	Cent. Low-Lift (Sturtevant)		6 in.	1921	1930	50	2,011	S
1			8 in.	1921	1930	50	2,409	S
1			10 in.	1921	1903	50	2,950	S
1	Cent. Low-Lift		1.5 mgd.	1922	1930	400	2,170	IS
1	Cent. High-Lift		3.0 mgd.	1922	1930	500	6,722	S
1	Cent. Low-Lift	Turbine	4.0 mgd.	1923	1930	500	6,006	S
1	Cent. High-Lift		5.0 mgd.	1924	1930	500	7,014	S
1	Cent. Low-Lift		5.0 mgd.	1924	1930	500	5,260	S
1	Cent. Well Pump			1925				
1	Cent. Basin Pump			1925				
1	Cent. Low-Lift		3.0 mgd.	1927				
1	Cent. High-Lift		3.0 mgd.	1927				
1	Cent. Low-Lift	Electric	8.0 mgd.	1927				
1	Cent. High-Lift		6.0 mgd.					
1	Cent. Low-Lift		15.0 mgd.	1927				
1	Cent. High-Lift		12.0 mgd.	1927				

* Purchased second-hand 1902.

SUMMARY OF CLASS B FACILITIES (contd.)

Miscellaneous Pumping Plant Equipment

No.		Year Installed	Year Retired	Salvage Value	Cost	Cause of Retirement
1	Electric Switchboard and Power Wiring	1927				
2	175-hp. Phoenix Boilers	1912	1930	$ 200		S
1	Walsh & Weidner Boiler	1923	1930	400	$ 8,155	S
1	Walsh & Weidner Boiler	1925	1930	400	7,430	S
1	Condenser	1922	1930	1,000	5,354	S
1	Condenser	1925	1930	2,500	20,995	S
1	16-in. Venturi Meter	1921				
1	30-in. Venturi Meter	1925				
1	20-in. Venturi Meter	1922	1930	Scrap	1,199	D
1	Dry Feed Machine	1936				
1	Dry Feed Machine	1924	1936	100	550	O
1	Wallace and Tiernan Ammoniator	1935				
2	Wallace and Tiernan Chlorinator	1925				
1	Wallace and Tiernan Chlorinator	1940				
2	Alum Feed Machines	1921	1930	Scrap	1,083	OS
3	Alum Feed Machines	1927				
3	Alum Hoppers and Scales	1927				
	Purification Structures					
2	Concrete Sedimentation Basins	1921				
2	Concrete Sedimentation Basins	1926				
1	3-mil.gal. Concrete Filter Unit	1921	1930	None	37,033	S
1	3-mil.gal. Concrete Filter Unit	1925	1930	None	36,816	S
4	5-mil.gal. Concrete Filter Unit	1927				
	Source of Supply					
1	Concrete Spillway	1938				
	Tanks and Reservoirs					
1	0.5-mil.gal. Steel Tank and Tower	1922	1940	None	44,376	G
1	2-mil.gal. Steel Standpipe	1925				
1	400,000-gal. Standpipe *	1912				
1	250,000-gal. Steel Tank and Tower	1927				
1	400,000-gal. Concrete Clear Well	1921				
1	1-mil.gal. Concrete Clear Well	1927				
1	1-mil. gal. Concrete Reservoir	1940				

* Gunite lining added in 1938.

Symbols: O—Obsolescence
D—Functional Depreciation
S—Supercession—Steam to Electric
I—Inadequacy
G—Governmental Order

TABLE 1

SUMMARY OF MAINS

WEST PALM BEACH, FLORIDA

Size, *in.*	Kind	No. of Feet Installed	Percentage of Total	No. of Feet Retired	Percentage of Total	No. of Feet in Service	Percentage of Total	Year of First Installation	Average Age, *yr.*
2	Cast-iron unlined	8,679	1.3	0	0	8,679	1.5	1925	15.5
4		94,719	14.4	52,683	55.5	42,036	7.5	1901	26.3
6		73,038	11.1	9,987	10.5	63,051	11.2	1894	24.2
8		64,557	9.8	21,644	22.8	42,913	7.6	1894	22.8
10		5,635	0.9	0	0	5,635	1.0	1921	16.9
12		2,670	0.4	0	0	2,670	0.5	1922	18.5
14		4,585	0.7	0	0	4,585	0.8	1914	26.5
16		8,251	1.2	2,530	2.7	5,721	1.0	1920	17.2
20		1,160	0.2	0	0	1,160	0.2	1921	19.5
2¼	Cast-iron, cement-lined	11,041	1.7	0	0	11,041	2.0	1938	2.5
4		1,069	0.2	134	0.1	935	0.2	1929	9.0
6		165,282	25.1	475	0.5	164,807	29.3	1925	13.3
8		112,462	17.1	7,550	7.9	104,912	18.6	1924	12.2
10		15,175	2.3	0	0	15,175	2.7	1925	15.0
12		31,884	4.8	0	0	31,884	5.7	1925	12.2
16		28,424	4.3	0	0	28,424	5.0	1925	11.1
20		17,475	2.7	0	0	17,475	3.1	1925	14.4
24		11,361	1.7	0	0	11,361	2.0	1926	14.2
30		645	0.1	0	0	645	0.1	1925	15.5
TOTAL		658,112	100.0	95,003	100.0	563,109	100.0		16.0
Percentage of Total		100.00		14.44		85.56			
Average Size, *in.*		7.9		5.8		8.3			

Mortality Survival Ratios

Size, *in.*	Kind	No. of Feet	Period Covered *yr.*	Percentage
2	Cast-iron unlined	8,679	15.5	100.000
4		94,719	39.5	27.390
6		73,038	46.5	83.935
8		64,557	45.5	44.223
10 and 12		8,305	19.5	100.000
Over 12		13,996	26.5	81.923
2¼	Cast-iron cement-lined	11,041	2.5	100.000
4		1,069	11.5	87.465
6		165,282	15.5	99.527
8		112,462	16.5	92.436
10–30		104,964	15.5	100.000
TOTAL		658,112		

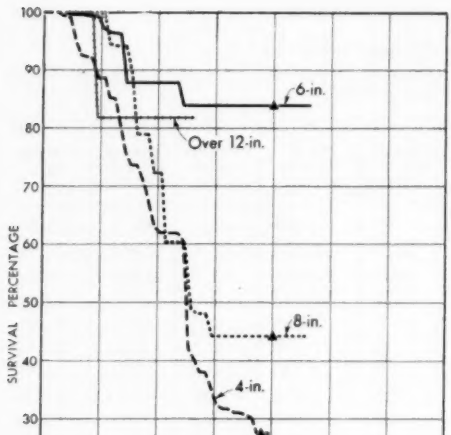


FIG. 1. Mortality Survival Curve—4–23-in. Cast-Iron Unlined Mains—West Palm Beach, Florida

BASE: Feet	SURVIVAL: 1894–1940	
SIZE	EXPOSURES	RETIREMENTS
in.	*ft.*	*ft.*
4	94,719	52,683
6	73,038	9,987
8	64,557	21,644
10 and 12	8,305	0
Over 12	13,996	2,530

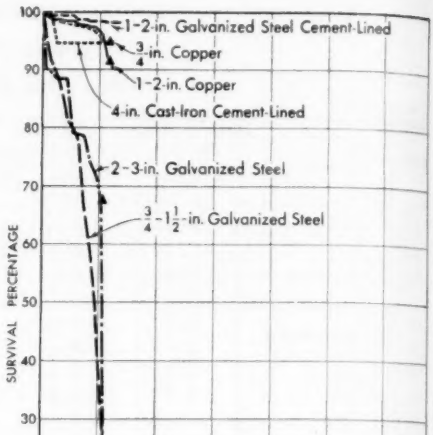


FIG. 2. Mortality Survival Curve—¾–4-in. All Mains—West Palm Beach, Florida

BASE: Feet		SURVIVAL: 1927–1940	
SIZE	KIND	EXPOSURES	RETIREMENTS
in.		*ft.*	*ft.*
¾–1½	Galvanized Steel	7,939	3,583
2–3	Galvanized Steel	2,126	578
1–2	Galvanized Steel Cement-Lined	79,588	1,372
¾	Copper	37,494	840
1–2	Copper	33,215	722
4	Cast-Iron Cement-Lined	279	14

Causes of Retirement

Two factors have influenced early retirement of certain sections of pipe installed in the service area, namely, the effect of the corrosive action of sea water and the corrosive nature of the water served. Prior to about 1920, and in the period 1926–1935, the water served was quite corrosive. Between 1920 and 1926 a greater use of well water reduced its corrosive nature.

Table 3 is a summary of notes relative to the retirement, reconditioning, cement lining and reinstallation of a considerable portion of the larger size pipe which are shown in the tables as retired.

Acknowledgment

The collection and compilation of data pertaining to the West Palm Beach Water Company were under the supervision of R. W. Reynolds, Superintendent.

TABLE 2

SUMMARY OF SERVICES

WEST PALM BEACH, FLORIDA

Size, *in.*	Kind	No. of Feet Installed	No. of Feet Retired	No. of Feet in Service	Year of First Installation	Average Age, *yr.*
¾	Galvanized steel	4,440	1,784	2,656	1929	5.5
1		1,797	1,299	498	1929	7.4
1¼		525	272	253	1929	7.6
1½		1,177	228	949	1929	5.8
2		2,107	578	1,529	1929	4.3
3		19	0	19	1929	11.2
1	Galvanized steel cement-lined	27,788	784	27,004	1927	10.9
1¼		27,296	294	27,002	1927	13.0
1½		17,053	0	17,053	1927	12.5
2		7,451	294	7,157	1927	11.9
¾	Copper	37,494	840	36,654	1928	4.4
1		22,876	407	22,469	1928	4.9
1¼		1,576	11	1,565	1930	4.7
1½		4,236	213	4,023	1928	4.9
2		4,527	91	4,436	1930	4.8
4	Cast-iron	279	14	265	1930	6.7
TOTAL		160,641	7,109	153,532		8.5
Percentage of Total		100.00	4.43	95.57		

Mortality Survival Ratios

Size, *in.*	Kind	No. of Feet	Period Covered *yr.*	Percentage
¾–1½	Galvanized steel	7,939	11.5	24.608
2 and 3	Galvanized steel	2,126	11.5	4.839
1–2	Galvanized steel cement-lined	79,588	13.5	98.153
¾	Copper	37,494	12.5	94.901
1–2	Copper	33,215	12.5	89.791
4	Cast-iron	279	10.5	94.531
TOTAL		160,641		

TABLE 3

NOTES ON RETIREMENT OF PIPE
WEST PALM BEACH, FLORIDA

4-in. Cast-Iron Unlined

546 ft. of pipe laid in 1920 and retired in 1929 were relaid as unlined pipe in 1929.

486 ft. of the above 546 ft. were retired in 1932.

Balance of 4-in. pipe retirements abandoned as not economically recoverable or sold as second-hand pipe.

6-in. Cast-Iron Unlined

4,449 ft. of pipe laid in 1916 and retired in 1930 were reconditioned, cement-lined and relaid in 1930 and are still in service.

1,248 ft. of pipe laid in 1916 and retired in 1930 were reconditioned, cement-lined and relaid in 1931 and are still in service.

8-in. Cast-Iron Unlined

2,989 ft. of pipe laid in 1894 and retired in 1905 were relaid as unlined pipe in 1905.

2,989 ft. of pipe laid in 1894 and retired in 1915 were relaid as unlined pipe in 1915.

5,978 ft. of pipe, above noted, retired in 1930, were reconditioned, cement-lined and relaid in 1930 and are still in service.

284 ft. of pipe laid in 1925, retired in 1937, were reconditioned, cement-lined and relaid in 1939 and are still in service.

7,550 ft. of cement-lined pipe laid in 1926, retired in 1930, were reconditioned, cement-lined and relaid in 1930–31 and are still in service. This pipe, though listed as cement-lined, was found to have only a light cement wash.

5,637 ft. of pipe laid in 1922, retired in 1938 were reconditioned, cement-lined and relaid in 1938–39–40 and are still in service.

16-in. Cast-Iron Unlined

1,830 ft. of pipe laid in 1920, retired in 1929 were reconditioned, cement-lined and relaid in 1930 and are still in service.

188 ft. of pipe laid in 1920, retired in 1929 were reconditioned, cement-lined and relaid in 1940 and are still in service.

Above pipe was installed in salt water and 512 ft. of pipe retired in 1929 were unfit for further service.

Summary of Installations and Retirements
West Palm Beach, Florida

Mains

2-in. Cast-Iron Unlined Mains

Year Installed	*Feet*		
	Installed	*In Service*	*Retired*
1925	8,679	8,679	0
1940	0	0	0
Total	8,679	8,679	0

4-in. Cast-Iron Unlined Mains

Year Installed	*Feet*		
	Installed	*In Service*	*Retired*
1901	23,064	9,074	13,990
1903	3,060	1,246	1,814
1905	3,060	1,314	1,746
1911	2,150	0	2,150
1912	11,162	5,753	5,409
1913	680	680	0
1915	7,548	0	7,548
1916	9,960	5,766	4,194
1917	5,740	1,135	4,605
1918	5,975	5,374	601
1919	3,256	0	3,256
1920	6,113	340	5,773
1924	3,745	2,730	1,015
1925	7,374	7,374	0
1926	1,040	1,040	0
1929	546	60	486
1930	96	0	96
1939	150	150	0
1940	0	0	0
Total	94,719	42,036	52,683

Retirements by Years

Year Installed	*Feet*	*Year*	*Feet*	*Year*	*Feet*	*Year*
1901	1,055	1925	10,880	1926	517	1930
	1,042	1931	256	1932	240	1937
1903	780	1930	1,034	1940		
1905	521	1932	786	1938	310	1938
	129	1940				
1911	2,150	1925				
1912	3,105	1925	1,030	1926	183	1931
	1,091	1938				
1915	1,300	1921	3,248	1926	3,000	1934
1916	1,135	1929	505	1930	2,009	1934
	545	1936				

4-in. Cast-Iron Unlined Mains (contd.)

Retirements by Years (contd.)

Year Installed	*Feet*	*Year*	*Feet*	*Year*	*Feet*	*Year*
1917	450	1922	680	1931	2,280	1934
	1,195	1935				
1918	470	1925	131	1930		
1919	1,120	1925	2,136	1934		
1920	3,275	1925	310	1928	2,188	1929
1924	1,015	1933				
1929	486	1932				
1930	96	1934				

6-in. Cast-Iron Unlined Mains

Year Installed	*Feet*		
	Installed	*In Service*	*Retired*
1894	2,422	2,422	0
1895	4,220	4,220	0
1901	3,074	1,574	1,500
1906	850	850	0
1912	5,387	5,387	0
1913	1,082	1,082	0
1915	1,752	1,752	0
1916	20,030	14,240	5,790
1917	2,020	2,020	0
1918	3,262	2,947	315
1920	1,950	1,950	0
1921	1,292	1,292	0
1922	3,575	2,918	657
1924	13,390	11,665	1,725
1925	2,415	2,415	0
1926	2,527	2,527	0
1927	3,790	3,790	0
1940	0	0	0
Total	73,038	63,051	9,987

Retirements by Years

Year Installed	*Feet*	*Year*	*Feet*	*Year*	*Feet*	*Year*
1901	1,500	1925				
1916	5,790	1930				
1918	315	1925				
1922	545	1929	112	1934		
1924	137	1928	105	1930	990	1934
	493	1935				

8-in. Cast-Iron Unlined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1894	6,700	0	6,700
1895	3,000	3,000	0
1901	4,574	4,574	0
1905	7,219	1,474	5,745
1912	715	715	0
1913	725	725	0
1914	1,250	1,250	0
1915	2,989	0	2,989
1918	550	550	0
1922	10,990	5,064	5,926
1923	18,725	18,725	0
1925	5,390	5,106	284
1926	1,600	1,600	0
1931	130	130	0
1940	0	0	0
Total	64,557	42,913	11,644

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1894	3,400	1905	3,300	1915		
1905	1,770	1924	2,989	1930	186	1931
	800	1934				
1915	2,989	1930				
1922	5,926	1938				
1925	284	1937				

10-in. Cast-Iron Unlined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1921	1,920	1,920	0
1925	3,715	3,715	0
1940	0	0	0
Total	5,635	5,635	0

12-in. Cast-Iron Unlined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1922	2,670	2,670	0
1940	0	0	0
Total	2,670	2,670	0

14-in. Cast-Iron Unlined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1914	4,585	4,585	0
1940	0	0	0
Total	4,585	4,585	0

16-in. Cast-Iron Unlined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1920	2,530	0	2,530
1923	4,108	4,108	0
1924	1,613	1,613	0
1940	0	0	0
Total	8,251	5,721	2,530

Retirements by Years

Year Installed	Feet	Year
1920	2,530	1929

20-in. Cast-Iron Unlined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1921	1,160	1,160	0
1940	0	0	0
Total	1,160	1,160	0

2¼-in. Cast-Iron Cement-Lined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1938	10,669	10,669	0
1939	219	219	0
1940	153	153	0
Total	11,041	11,041	0

4-in. Cast-Iron Cement-Lined Mains

Year Installed	Feet		
	Installed	In Service	Retired
1929	80	80	0
1930	350	216	134
1931	39	39	0
1932	486	486	0
1934	114	114	0
1940	0	0	0
Total	1,069	935	134

4-in. Cast-Iron Cement-Lined Mains (contd.)

Retirements by Years

Year Installed	Feet	Year
1930	134	1934

6-in. Cast-Iron Cement-Lined Mains

Year	Feet		
Installed	Installed	In Service	Retired
1925	12,837	12,362	475
1926	87,647	87,647	0
1927	34,265	34,265	0
1928	5,795	5,795	0
1929	1,885	1,885	0
1930	5,922	5,922	0
1931	5,629	5,629	0
1932	557	557	0
1933	1,003	1,003	0
1934	6,591	6,591	0
1935	2,619	2,619	0
1940	532	532	0
Total	165,282	164,807	475

Retirements by Years

Year Installed	Feet	Year
1925	475	1939

8-in. Cast-Iron Cement-Lined Mains

Year	Feet		
Installed	Installed	In Service	Retired
1924	5,400	5,400	0
1925	4,930	4,930	0
1926	65,655	58,105	7,550
1927	7,096	7,096	0
1928	6,084	6,084	0
1929	1,371	1,371	0
1930	9,582	9,582	0
1931	3,876	3,876	0
1934	790	790	0
1935	779	779	0
1937	767	767	0
1938	1,675	1,675	0
1939	2,264	2,264	0
1940	2,193	2,193	0
Total	112,462	104,912	7,550

Retirements by Years

Year Installed	Feet	Year
1926	7,550	1930

10-in. Cast-Iron Cement-Lined Mains

Year	Feet		
Installed	Installed	In Service	Retired
1925	8,705	8,705	0
1926	6,160	6,160	0
1928	310	310	0
1940	0	0	0
Total	15,175	15,175	0

12-in. Cast-Iron Cement-Lined Mains

Year	Feet		
Installed	Installed	In Service	Retired
1925	7,828	7,828	0
1926	2,811	2,811	0
1927	9,800	9,800	0
1929	4,657	4,657	0
1930	994	994	0
1935	5,367	5,367	0
1937	427	427	0
1940	0	0	0
Total	31,884	31,884	0

16-in. Cast-Iron Cement-Lined Mains

Year	Feet		
Installed	Installed	In Service	Retired
1925	12,465	12,465	0
1926	38	38	0
1927	3,833	3,833	0
1930	5,748	5,748	0
1937	446	446	0
1939	4,533	4,533	0
1940	1,361	1,361	0
Total	28,424	28,424	0

20-in. Cast-Iron Cement-Lined Mains

Year	Feet		
Installed	Installed	In Service	Retired
1925	4,085	4,085	0
1926	10,995	10,995	0
1927	1,352	1,352	0
1931	1,043	1,043	0
1940	0	0	0
Total	17,475	17,475	0

24-IN. CAST-IRON CEMENT-LINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1926	7,995	7,995	0
1927	3,366	3,366	0
1940	0	0	0
TOTAL	11,361	11,361	0

30-IN. CAST-IRON CEMENT-LINED MAINS

Year Installed	Feet Installed	Feet In Service	Feet Retired
1925	645	645	0
1940	0	0	0
TOTAL	645	645	0

SERVICES

¾-IN. GALVANIZED STEEL SERVICES

Year Installed	Feet Installed	Feet In Service	Feet Retired
Not Complete Before 1929			
1929	1,041	595	446
1930	435	37	398
1931	427	32	395
1932	284	80	204
1933	37	15	22
1934	256	229	27
1935	33	14	19
1936	279	195	84
1937	348	277	71
1938	1,179	1,097	82
1939	116	85	31
1940	5	0	5
TOTAL	4,440	2,656	1,784

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1929	26	1930	2	1933	10	1934
	6	1935	29	1936	4	1937
	47	1938	132	1939	190	1940
1930	19	1933	21	1934	9	1936
	22	1937	68	1938	76	1939
	183	1940				
1931	18	1931	20	1932	112	1935
	29	1936	93	1938	62	1939
	61	1940				
1932	9	1932	72	1933	7	1934
	3	1936	32	1938	62	1939
	19	1940				
1933	1	1935	1	1937	5	1938
	1	1939	14	1940		
1934	1	1936	8	1938	18	1939
1935	8	1937	1	1938	7	1939
	3	1940				
1936	1	1936	17	1938	42	1939
	24	1940				
1937	10	1938	57	1939	4	1940
1938	27	1938	50	1939	5	1940
1939	10	1939	21	1940		
1940	5	1940				

1-IN. GALVANIZED STEEL SERVICES

Year Installed	Feet Installed	Feet In Service	Feet Retired
1929	182	114	68
1930	323	44	279
1931	250	49	201
1932	200	47	153
1933	50	7	43
1934	41	34	7
1935	100	61	39
1936	100	36	64
1937	171	28	143
1938	300	45	255
1939	75	33	42
1940	5	0	5
TOTAL	1,797	498	1,299

1-in. Galvanized Steel Services (contd.)

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1929	1	1935	67	1940		
1930	5	1931	35	1934	1	1936
	22	1937	1	1938	4	1939
	211	1940				
1931	1	1935	11	1938	55	1939
	74	1940				
1932	11	1938	52	1939	90	1940
1933	33	1939	10	1940		
1934	7	1940				
1935	39	1939				
1936	18	1938	28	1939	18	1940
1937	6	1937	8	1938	41	1939
	88	1940				
1938	244	1938	9	1939	2	1940
1939	34	1939	8	1940		
1940	5	1940				

1¼-in. Galvanized Steel Services

Year Installed	Feet		
	Installed	In Service	Retired
1929	76	5	71
1930	90	19	71
1931	189	60	129
1932	71	71	0
1934	41	41	0
1936	46	45	1
1938	12	12	0
1940	0	0	0
Total	525	253	272

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1929	4	1934	4	1935	8	1938
	55	1940				
1930	12	1936	29	1937	9	1939
	21	1940				
1931	14	1936	77	1938	13	1939
	25	1940				
1936	1	1940				

1½-in. Galvanized Steel Services

Year Installed	Feet		
	Installed	In Service	Retired
1929	51	0	51
1930	160	156	4
1931	150	55	95
1932	231	230	1
1933	100	54	46
1934	50	38	12
1937	65	46	19
1939	370	370	0
1940	0	0	0
Total	1,177	949	228

1½-in. Galvanized Steel Services (contd.)

Retirements by Years

Year Installed	Feet	Year	Feet	Year
1929	51	1930		
1930	4	1940		
1931	13	1939	82	1940
1932	1	1940		
1933	10	1937	36	1940
1934	12	1935		
1937	19	1938		

2-in. Galvanized Steel Services

Year Installed	Feet		
	Installed	In Service	Retired
1929	276	0	276
1930	160	130	30
1931	232	221	11
1932	54	30	24
1936	173	165	8
1937	232	46	186
1938	535	533	2
1939	370	370	0
1940	75	34	41
Total	2,107	1,529	578

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1929	80	1934	1	1935	12	1938
	2	1939	181	1940		
1930	1	1930	8	1939	21	1940
1931	2	1938	9	1939		
1932	1	1939	23	1940		
1936	1	1937	6	1938	1	1939
1937	170	1937	16	1939		
1938	2	1938				
1940	41	1940				

3-in. Galvanized Steel Services

Year Installed	Feet Installed	Feet In Service	Feet Retired
1929	14	14	0
1930	5	5	0
1940	0	0	0
Total	19	19	0

4-in. Cast-Iron Services

Year Installed	Feet Installed	Feet In Service	Feet Retired
1930	117	117	0
1934	19	19	0
1935	22	22	0
1937	86	72	14
1938	12	12	0
1940	23	23	0
Total	279	265	14

Retirements by Years

Year Installed	Feet	Year
1937	14	1939

¾-in. Copper Services

Year Installed	Feet Installed	Feet In Service	Feet Retired
1928	243	240	3
1929	340	320	20
1930	3,472	3,355	117
1931	2,617	2,531	86
1932	1,797	1,762	35
1933	1,106	1,097	9
1934	2,521	2,519	2
1935	322	316	6
1936	3,083	2,998	85
1937	3,550	3,450	100
1938	6,054	5,895	159
1939	8,662	8,470	192
1940	3,727	3,701	26
Total	37,494	36,654	840

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1928	3	1934				
1929	2	1934	2	1936	16	1939
1930	15	1931	16	1934	11	1938
	29	1939	46	1940		

¾-in. Copper Services (contd.)

Retirements by Years (contd.)

Year Installed	Feet	Year	Feet	Year	Feet	Year
1931	24	1931	2	1934	35	1938
	20	1937	3	1939	2	1940
1932	2	1933	4	1934	16	1938
	13	1940				
1933	2	1936	7	1939		
1934	1	1934	1	1937		
1935	1	1937	5	1938		
1936	5	1936	18	1937	34	1938
	27	1939	1	1940		
1937	12	1937	32	1938	50	1939
	6	1940				
1938	4	1938	116	1939	39	1940
1939	156	1939	36	1940		
1940	26	1940				

1-in. Copper Services

Year Installed	Feet Installed	Feet In Service	Feet Retired
1928	252	240	12
1929	370	333	37
1930	3,814	3,792	22
1931	1,310	1,293	17
1932	552	523	29
1933	508	504	4
1934	2,218	2,152	66
1935	666	666	0
1936	1,821	1,816	5
1937	2,361	2,283	78
1938	1,566	1,551	15
1939	1,801	1,750	51
1940	5,637	5,566	71
Total	22,876	22,469	407

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1928	12	1940				
1929	12	1931	25	1935		
1930	7	1931	12	1938	3	1939
1931	17	1934				
1932	3	1933	26	1938		
1933	4	1939				
1934	66	1940				
1936	5	1936				
1937	21	1937	16	1938	38	1939
	3	1940				
1938	14	1938	1	1939		
1939	51	1939				
1940	71	1940				

1¼-IN. COPPER SERVICES

Year Installed	Feet		
	Installed	In Service	Retired
1930	125	125	0
1931	121	121	0
1932	135	128	7
1933	54	54	0
1934	415	415	0
1935	15	15	0
1936	50	50	0
1937	46	42	4
1940	615	615	0
TOTAL	1,576	1,565	11

Retirements by Years

Year Installed	Feet	Year
1932	7	1936
1937	4	1937

1½-IN. COPPER SERVICES

Year Installed	Feet		
	Installed	In Service	Retired
1928	274	274	0
1929	154	100	54
1930	364	304	60
1931	185	185	0
1932	146	146	0
1933	28	28	0
1934	435	435	0
1935	169	168	1
1936	125	125	0
1937	354	354	0
1938	494	494	0
1939	1,167	1,069	98
1940	341	341	0
TOTAL	4,236	4,023	213

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1929	3	1934	7	1938	44	1940
1930	40	1930	14	1934	3	1938
	3	1940				
1935	1	1937				
1939	98	1940				

2-IN. COPPER SERVICES

Year Installed	Feet		
	Installed	In Service	Retired
1930	523	460	63
1931	222	222	0
1932	231	231	0
1933	55	55	0
1934	980	980	0
1935	128	127	1
1936	250	250	0
1937	515	506	9
1938	360	354	6
1939	403	392	11
1940	860	859	1
TOTAL	4,527	4,436	91

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1930	3	1931	8	1938	52	1940
1935	1	1939				
1937	9	1937				
1938	4	1939	2	1940		
1939	1	1939	10	1940		
1940	1	1940				

1-IN. GALVANIZED STEEL CEMENT-LINED SERVICES

Year Installed	Feet		
	Installed	In Service	Retired
1927	11,760	11,713	47
1928	5,212	5,101	111
1929	2,470	2,376	94
1930	645	468	177
1931	430	427	3
1932	1,305	1,235	70
1933	652	638	14
1934	1,000	976	24
1935	305	297	8
1936	1,006	917	89
1937	1,669	1,546	123
1938	1,186	1,162	24
1939	132	132	0
1940	16	16	0
TOTAL	27,788	27,004	784

1-IN. GALVANIZED STEEL CEMENT-LINED SERVICES (contd.)

Retirements by Years

Year Installed	*Feet*	*Year*	*Feet*	*Year*	*Feet*	*Year*
1927	10	1930	37	1931		
1928	17	1931	6	1933	48	1934
	13	1937	27	1939		
1929	33	1929	3	1930	1	1932
	1	1935	7	1936	44	1938
	5	1939				
1930	5	1931	35	1934	1	1936
	1	1938	4	1939	131	1940
1931	3	1935				
1932	1	1932	9	1937	60	1939
1933	14	1939				
1934	2	1935	22	1939		
1935	8	1939				
1936	46	1936	3	1937	40	1938
1937	83	1937	14	1938	4	1939
	22	1940				
1938	21	1939	3	1940		

1¼-IN. GALVANIZED STEEL CEMENT-LINED SERVICES

Year	*Feet*		
Installed	*Installed*	*In Service*	*Retired*
1927	19,500	19,487	13
1928	4,880	4,880	0
1929	1,058	803	255
1930	1,368	1,343	25
1931	414	414	0
1936	76	75	1
1940	0	0	0
TOTAL	27,296	27,002	294

Retirements by Years

Year Installed	*Feet*	*Year*	*Feet*	*Year*
1927	13	1933		
1929	33	1934	222	1935
1930	25	1936		
1936	1	1936		

1½-IN. GALVANIZED STEEL CEMENT-LINED SERVICES

Year	*Feet*		
Installed	*Installed*	*In Service*	*Retired*
1927	11,900	11,900	0
1928	3,072	3,072	0
1929	92	92	0
1930	111	111	0
1931	721	721	0
1932	167	167	0
1933	8	8	0
1934	292	292	0
1936	249	249	0
1937	59	59	0
1938	327	327	0
1939	55	55	0
1940	0	0	0
TOTAL	17,053	17,053	0

2-IN. GALVANIZED STEEL CEMENT-LINED SERVICES

Year	*Feet*		
Installed	*Installed*	*In Service*	*Retired*
1927	4,070	4,049	21
1928	1,139	1,110	29
1929	739	715	24
1930	341	141	200
1931	28	28	0
1932	52	43	9
1933	25	25	0
1934	636	636	0
1935	165	154	11
1936	201	201	0
1937	11	11	0
1938	44	44	0
1940	0	0	0
TOTAL	7,451	7,157	294

Retirements by Years

Year Installed	*Feet*	*Year*	*Feet*	*Year*	*Feet*	*Year*
1927	18	1932	3	1935		
1928	29	1929				
1929	8	1930	2	1934	14	1935
1930	200	1938				
1932	9	1932				
1935	11	1939				

Abstracts of Water Works Literature

Key: In the reference to the publication in which the abstracted article appears, **34:** 412 (Mar. '42) indicates volume 34, page 412, issue dated March 1942. If the publication is paged by the issue, **34:** 3: 56 (Mar. '42) indicates volume 34, number 3, page 56, issue dated March 1942. Initials following an abstract indicate reproduction, by permission, from periodicals, as follows: *B.H.—Bulletin of Hygiene (British); C.A.—Chemical Abstracts; P.H.E.A.—Public Health Engineering Abstracts; W.P.R.—Water Pollution Research (British); I.M.—Institute of Metals (British).*

HEALTH AND HYGIENE

Fluorosis and Dental Caries on Tyneside. R. WEAVER. Brit. Dental J. (Br.) **76**: 29 ('44). Nutrition Absts. & Revs. **14**: 156 ('44). Water supply of North Shields obtained from Northumberland and contains less than 0.25 ppm. fluorine. South Shields obtains its water supply mainly from deep wells in magnesium limestone; recent sample contained 1.4 ppm. fluorine. Dietetic habits of 2 communities unlikely to differ very much owing to their close proximity and to similar indus., economic and social conditions. Dental examns. made of 1000 school children from each of 2 towns. Incidence of dental caries in 12-yr.-old school children from South Shields 56% of that in children of same age from North Shields. Intake of fluorine probably decisive factor.—*W.P.R.*

Water Purification When Amebic Dysentery Is Prevalent. U.S. Army Med. Dept. Bul. **4**: 127 ('45). Directives in India-Burma Theater provide precautions in water purif. where amebic dysentery prevalent. Using std. mobile or portable water purif. units, following procedures should be used: coagulant dosage to give heavy, rapidly settling floc employing batch treatment with min. settling period of 1 hr.; filter rates restricted to 10 gpm. for portable units and 60 gpm. for mobile units; chlorination to residual of 1 ppm. Using Lyster bags, chlorine dosages must produce 1 ppm. residual after 10-min. contact; in addn. 1 ampule of calcium hypochlorite should be added then and 30 min. more allowed before using water. Max. use of subsurface waters recommended. Since boiling does not insure against recontamn., chlorination should always be last step in purif. process. Boiled water should be cooled before chlorination, as chlorine is dissipated rapidly from hot water.—*Ed.*

Positive Influence of Water Supply on Health. MARGARET M. MURRAY & DAGMAR C. WILSON. Lancet. (Br.) 23 (July 7, '45). Authors point out that nutritional research has increased knowledge of health value of mineral contents of drinking water, and that implications of wholesome water must now be extended beyond usual neg. stds., to promotion of health and good nutrition by insuring most favorable mineral content in domestic supplies. Three minerals important: calcium, iodine and fluorine. Widdowson has shown that about one-fifth (200 mg.) of daily calcium requirement may be obtained by drinking hard water, and there seems to be evidence that hard water protects against dental caries. Reduction of permanent hardness to 15-20 parts per 100,000 should satisfy health requirements and water should not be too unpleasant for domestic use; lower values would be satisfactory if other sources of calcium adequate. Association of low iodine content and goiter well known, but there are many waters in Great Britian with iodine content of less than 3μg./l.; for these areas use of iodized salt has been recommended. Other waters have high iodine content, and suggestion made that these could be mixed with waters of low content. Fluorine present in many British waters, and it may be possible, by mixing waters from several sources, to adjust content to about 0.5 ppm., level considered desirable in relation to dental caries. Instances quoted of villages in England which cannot use good water supply, either because it is not provided, or because arrangements for drainage do not exist. Conclusion is that individual water schemes cannot be planned efficiently on parochial basis.—*B.H.*

The Relation of Water Supply to the Prevalence of Goiter. NORMAN J. HOWARD. Wtr. & Sew. **83**: 3: 23 (Mar. '45). Different investigators have variously attributed prevalence of goiter in certain areas to mineral content or presence of infective agent in water. Administration of I in proper doses has been shown of value in preventing thyroid enlargement, particularly in adolescents, but this does not necessarily prove it is deficiency disease. Evidence supporting parasitic theory appears conclusive, but incidence in adolescents high despite fact most large cities employ filtration and disinfection. Many supplies, however, derived from heavily pold. sources and infective agent, such as virus, may remain after purif. Field for research.—*R. E. Thompson.*

Concerning the Value and Significance of Minimum Requirements for Hygienic Evaluation of Water. Kleine Mitt. für Wasser-, Boden-u. Lufthyg. (Ger.) **18**: 115 ('42). Min. stds. set for drinking water; sometimes thought that raising such stds. has value for hygienic detn. of water. Presence of NH_3-N, NO_2-N, NO_3-N, chlorides, Fe, Mn, O_2, CO_2, may in some cases indicate poln. of undesirable conditions for domestic use, but has nothing to do with the hygienic value of the water. In good water usually find nitrogen compds. below 10 ppm., O.C.12, Cl_2 30, P_2O_5 traces, SO_3 60, K_2O rate, total hardness 250, total solids 500; such waters suitable and variations in constituents should not be considered of hygienic importance.—*Willem Rudolfs.*

Epidemic Diarrhea, Nausea and Vomiting of Unknown Cause. HOBART A. REIMAN, JOHN H. HODGES & ALISON H. PRICE. J. Am. Med. Assn. **27**: 1: 1 (Jan. 6, '45). Discusses widespread prevalence of large and small outbreaks of mild acute gastro-intestinal disturbance observed in United States, Germany, Canada, England, Denmark, Australia and elsewhere. Very probably not a "new" disease entity, but almost certain that it is widespread communicable, endemic, sporadic and at times epidemic disease or group of diseases, apart from known forms of dysentery and acute food poisoning which, because of its mildness, usually passes unnoticed. Epidemics occur at all times of year but especially in autumn, and in different groups from 15 to 100% of persons involved. Incubation period estd. as between 30 hr. and 7 day In majority of published reports symptom in approx. order of frequency anorexia nausea, vomiting, diarrhea, dizziness, achin and abdominal discomfort or cramps. Caus of disease unknown, but all who have studie it believe it to be infectious and communicable Food, milk and water often suspected, bu have usually been elimd. as sources. Tw outbreaks reported in detail. Probably a air-borne infection, but hand to mouth o other means of transmission cannot be ex cluded, nor is it known whether it enter through respiratory tract or digestive tract In view of present uncertainty seems best t report disease as nonseasonal, contagious and infectious, affecting predominantly gastro-intestinal tract, and not caused by any o known infectious agents but possibly of viral origin.—*J. H. O'Neill.*

Outbreaks of Disease in the United States During 1943, Transmitted by Water, Milk and Milk Products, and Other Foods. U.S. Pub. Health Repts. **60**: 491 (May '45). List of outbreaks of disease transmitted through water, milk and milk products and other food products, as reported by the state health authorities in '43, includes variety of enteric and other diseases and number of different foods. Review of data reveals that disregard of fundamental san. principles caused considerable amt. of preventable illness and mortality in this country in '43. This report deals only with outbreaks and therefore does not include all cases of diseases transmitted by water and food products. 380 such outbreaks reported in '43 caused approx. 24,000 cases and 56 deaths. Although not as important numerically as other diseases conveyed by means of food and water, botulism resulted in highest fatality rate, with 10 cases and 7 deaths, in all of which source reported to be home-canned foods. Outbreak of botulism occurring in New Mexico, reported due to eating of home-canned pumpkin, resulted in 4 cases and 4 deaths. Gastro-enteritis and typhoid fever principal water-borne diseases. Most usual causes of water-borne epidemics lack of, or improper, chlorination and inadequate protection of water supplies from surface drainage and seepage from sewage. Among most important sources of contamn. which caused milk and milk product outbreaks were lack of, or improper, pasteurization, improper

Outbreaks of Disease in the United States During 1943, Conveyed by Water, Milk and Milk Products and Other Foods

Medium	Number of Outbreaks	Number of Cases	Number of Deaths	Principal Diseases in Outbreaks	Principal Food Involved or Suspected Source of Water
Water	26	5,612	15	Gastro-enteritis and typhoid fever	Public well, school well, private well, surface supply, irrigation ditch—principally untreated.
Milk and milk products	40	1,590	7	Diphtheria, food poisoning, gastro-enteritis, scarlet fever and typhoid fever	Sweet milk, ice cream, cheese, milk shakes and buttermilk.
Foods other than milk products	285	13,938	33	Dysentery, chemical or bacterial food poisoning, gastro-enteritis, typhoid fever, paratyphoid fever, scarlet fever, trichinosis and botulism	Home-canned mushrooms, tomatoes, peas, pumpkin and string beans; fish, ham, stew, soup, meat, and egg salad sandwiches, chicken and dressing, eggs, cake, custard, potato salad, pie, shrimp salad, turkey dressing, sausage, raw oysters, souse, baked beans, cream puffs, cream pastry, creamed potatoes, chocolate eclair, tapioca pudding.
Undetermined vehicle	38	2,525	1	Dysentery, food poisoning, gastro-enteritis (including *Salmonella* infection), typhoid fever	
Total	389	23,665	56		

cleansing of utensils, bulk-milk contamn. and carriers. Food poisoning and gastro-enteritis involved in 60% of milk-borne outbreaks. Foods other than milk and milk products responsible for 73% of outbreaks, 59% of cases and 59% of deaths. Some of causes or means of contamn. reported were home-canned foods; lack of, or improper, refrigeration; infected food handlers; careless or improper handling in prepn. of salads; insufficient cooking; and possible infection by rodents and flies. Food poisoning and gastro-enteritis were involved in 89% of food-borne outbreaks. Table summarizes briefly report issued by Div. of San. Eng. U.S.P.H.S. —*Ed.*

CROSS-CONNECTIONS AND PLUMBING

Cross-Connections at Army Installations. H. H. GERSTEIN. U.S. Army Med. Dept. Bul. **4**: 203 ('45). Some bldgs. converted for army use have presented problems in cross-connection hazards. These hazards accentuated by army pop. several times greater than contemplated in original design, thus causing intensive use of toilets, lavatories, baths and showers during short periods of time. Under these abnormal conditions, inadequacies in piping due to corrosion or too small a size showed up serious hazards due to plumbing defects which would not have been recognized under normal civilian loads. At

one hotel installation, demands on water system caused vacuums in hot and cold water supply piping as great as 10" of mercury. Recommended that undersized piping be reinforced with addnl. supply lines to prevent vacuum in system. At another hotel installation, flushometer valves were of a type which could easily permit back-siphonage of toilet contents. Here real health hazard existed because of frequent vacuums in heavily loaded hot and cold piping. As temporary measure to minimize hazard of back-siphonage, periods of use by troops of plumbing fixtures staggered to prevent negative pressures in piping. Serious hazard of similar nature found in bldg. occupied by private school which contracted to train army personnel. Water supply system for this bldg. consisted of booster pump and pressure tank located in basement, which boosted water pressure sufficiently to supply plumbing fixtures up to 8th floor. Since school ordinarily closed on Saturday afternoon and Sunday, bldg. management shut off power to booster pump during this period. However, some students would work at school during this period to catch up in their studies and, while there, would use toilet fixtures. Reported that as fixtures flushed, water pressure would fall rapidly until it reached city pressure, which was only sufficient to bring water up to the 4th or 5th floor. During such time, apparent that vacuum was formed in piping above 5th floor, and, since none of flushometer valves on toilets furnished with vacuum, possible to back-siphon contents of toilets into water supply system every time toilet on upper floors flushed and thus contam. water drawn from drinking fountains on lower floors. At time of survey, toilet on 8th floor stopped up and bowl full of water and feces up to top of rim, thus creating ideal condition for back-siphonage. Policy of army is to discontinue use of private well water supplies and use of secondary water from condensers and hydr. elevators because of possibility of either becoming contamd. and because of possible dangerous cross-connections between these systems and drinking water supply. At one installation abandonment of secondary water not feasible but hazard elimd. by post-chlorination. One of most serious conglomerations of plumbing defects found in water system in hotel occupied by army. These defects summarized as follows: (1) Small reservoir tank, in which hot condensate from heating system stored, located in sump in subbasement s that excess condensate could overflow int sump. Hot condensate from reservoi pumped into hot water system to make us of hot soft water. Top of condensate reservoir located at el. below top of sump. Number of drains from various sources dischgd. into sump. If sump pump, which dischgd. directly to city sewer, failed to operate, possible for drainage wastes to fill sump and overflow into and pol. contents of condensate reservoir and from there be pumped into hot water system. (2) Similar but more serious hazard would result from backing up of sewage from city sewer into sump through sump pump dischg. (3) Branch from sump pump dischg. line terminated in open end directly over open top of house water tank. By opening valve on this line, possible, if check valve leaked, to pump sump waste into house tank. (4) Also possible for sewage from city sewer to leak back through sump pump dischg. line into house tank. (5) Connection in (4) installed to permit condenser water which normally flowed into house tank to be diverted into sewer and by that token exposed water in condenser line to poln. from sewer through direct connection. (6) Direct connection between sump pump dischg. line and hot water system for purpose of draining hot water system to sewer. Through this connection, possible to pump sump waste into hot water lines. (7) Sewage from city sewers could also flow back into hot water system through connection described in (6). All new hospital fixtures purchased by army under specifications required to be protected against back-siphonage. Sterilizers, water stills, bedpan washers and dental fixtures all have vacuum breakers incorporated in fixtures. At one post where delivery of new dental fixtures could not be obtained, used dental fixtures purchased on market protected by installation of vacuum breakers in water supply connections. Sanitarians and plumbers frequently overlook relative hazards from various types of plumbing defects and inclined to consider them all as being equally dangerous. Often impossible, because of lack of funds, materials and labor, to correct at once all plumbing defects found. One must then evaluate relative hazards of various types of defective connections and direct his efforts to correction, first of most dangerous defect, leaving those from which hazard more remote for later correction. "Hot" 2" cross-connection between

safe water and pold. river water many times more hazardous than faucet whose orifice submerged about ¼" below rim of lavatory fixture. Efforts should be directed to break direct connection immediately and to correction of other when time and funds permit. In making plumbing survey for purpose of finding cross-connections and plumbing deficits in system, investigator will find suit of fatigue coveralls as essential as for carrying out thorough survey. Before looking for plumbing defects, important that flow diagram be prepd. which shows all booster pumps and reservoirs which carry flow of main potable water supply through system and which also shows piping layout and pumps and reservoirs on all secondary water supplies and other piping systems on premises. Diagram will help investigator in deciding where to look for cross-connections. Process equip. then checked for submerged inlet connections and direct sewer connections; plumbing fixtures checked for possibility of back-siphonage, pumps checked for priming connections and checks made for other types of plumbing defects. Mistake often made in investigating plumbing system suspected of causing illness is to place blame on first plumbing defect found in system. Illness might have been caused by infected food instead of by plumbing defects. Necessary to det. that conditions in system such as to cause plumbing defects to become operative to cause poln. of system before placing blame on particular plumbing defect. Mere existence of plumbing defect not presumptive evidence that it caused illness.—*Ed.*

Double-Check Valve Performance. FREDERICK O. A. ALMQUIST. W. W. & Sew. **90**: 329 (Sept. '43). Public Health Council of Conn. State Dept. of Health, on July 12, '26, adopted regulations regarding cross-connections which stated, in effect: Reg. 118. After Dec. 31, '26, no phys. connection between distr. system of public potable water supply and that of any other water supply shall be permitted, unless such other water supply is of safe san. qual. and interconnection of both supplies approved by state dept. of health. . . . *Provided:* That where such phys. connections exist on Dec. 31, '26, and include 2 gate valves with indicator posts, 2 check valves of design approved by state dept. of health with drip cocks and gages for testing, all located in vault of water-tight constr. readily accessible for periodic inspection, date of discontinuance may be temporarily extended, with permission of state dept. of health. Number of mfrs. took advantage of provision in regulation and in '27, 162 check valved installations in 100 factories. Conn. State Dept. of Health does its own testing of check valve installations. Author gives types of check valves used, procedure for testing, difficulties in testing and results of 8550 tests made on avg. of 156 cross-connections from Jan. 1, '27, to June 30, '42, which showed 156 leaks in outside check valves, 19 leaks in inside check valves and 7 in both check valves; since '29, only 1 installation found leaking in both check valves. Tests first made every 2 mo., but for past 6 yr. once every 4 mo.—*C.A.*

Vacuums in Potable Water Supplies. *From San. Inspectors Manual. La. State Bd. of Health.* Plbg.-Drainage Topics **4**: 11: 2 (Nov. '43). In '36, Natl. Assn. of Master Plumbers established research program at Inst. of Hydr. Research, State Univ. of Iowa, on back-siphonage and resultant poln. of water supplies. *Conclusions:* (1) Vacuum formations in water pipes not all explained in terms of simple siphon. Neg. pressures in complicated piping systems due to pressure loss by friction common. (2) Pold. water from few submerged inlet fixtures can pol. entire bldg. piping system and may reach street mains. (3) Vacuums in bldg. pipe systems can be caused by water hammer pressure waves, local restrictions in pipes, and stream condensation in hot water tanks. (4) Air flow through any opening in pipe harboring partial vacuum will reach max. value at 15" of mercury, but not increase with deg. of vacuum. (5) Separate water supply to submerged inlet fixtures not practical and adequate means of elimg. water poln. danger because cross-connection enhanced by dual (safe and unsafe) supplies and it cannot be used for submerged inlet fixtures requiring sure water supply or for hot water fixtures. (6) Air inlets at tops of water risers and other points for vacuum prevention not proper soln. to back-siphonage problem. From pneumatic standpoint, entire prevention impossible, and air-inlet devices installed under const. water pressures entirely undependable. (7) Correct and only soln. is elimn. and correction of individual unsafe fixture. Latter fundamental evil in plumbing system making back-siphonage possible. (8) Inlets should be raised above fixture top to distance equal to value from one of 2

formulas, $G = 2D$, or, $G = 2\frac{1}{4}$ times square root of A, where G is gap in inches, D diam. of inlet, and A min. area of inlet. This will prevent siphonage and provide safety factor. Heights of gaps recommended for common fixture types: lavatory, 1″; kitchen sink and laundry trays, 1½″; bathtub, 2″. (9) With certain exceptions, raising inlets above overflows connected to atm. directly or indirectly, not considered ideal solution. (10) Vacuum-breaking principle as defined herein has necessary requisites for proper soln. to back-siphonage problem. Proper application entails rigid requirements relating to vacuum-breaking device used. (11) Recommended vacuum-breaking principle acceptance as tentative std. for proper solution if vacuum breakers used meet all report requirements; and that such devices on actual installation be carefully observed several years to note performance characteristics before definitely accepting as std. (12) Tank closet with constantly submerged inlet nearly greatest back-siphonage hazard in plumbing system. Mfrs. should try to have entire float valve and water supply piping connections installed above tank overflow level if tank water subject to sewage poln. Unless especially well designed, moving part vacuum-breaking devices not recommended in closet tanks because of corrosive conditions. (13) Automatic flush valve fixtures should be protected from back-siphonage by incorporating: loose check valve in stop valve; stable unit piston in case of piston type valve; vacuum breaker between control valve and fixture meeting requirements; and no water supply connection to closet bowl below flush rim should be permitted. (14) Frost-proof closet presents such pronounced water poln. hazards that use under best conditions unsatisfactory. (15) Many hospital fixtures excellent examples of water poln. hazards. (16) Special water supply and plumbing equip. mfrs. should avoid introducing back-siphonage hazards into designs and, where possible, use inlet-above fixture top. (17) Best way to elim. direct cross-connections with auxiliary private water supplies is to elim. wholesale presence of latter in bldgs. served with pub. supply. Regulations and inspections not entirely effective otherwise. (18) Directly connecting city water to cooling and condensing systems in gas compressors, refrig. app., and air-conditioning equip. should be condemned. Re-use of such water in domestic supply systems of bldgs. unsatisfactory from san. standpoint. (19) Submerged inlet water supply connections for air washing cooling, humidifying and dehumidifying should not be allowed. (20) In bldgs., water flowing in long pipe under gravity should never be used again in domestic system as chance too great for its use for waste connection. (21) Tests indicate vacuum causing air flow through rim ports of closet bowls and urinals, or through or over surfaces likely to have pold. liq. drops adhering, should not be over 1″ of water to prevent picking up and carrying back such droplets as spray into water-supply pipes. (22) Most vacuums occurring in water pipes caused by improper pipe sizing, fittings and valves introducing excessive friction loss. Properly sized and installed water systems would prevent at least 90% of all vacuum formations.—*Ralph E. Noble.*

Cross-Connections in North Dakota. Wesley E. Gilbertson. Plumbg.-Drainage Topics. **4**: 8: 2 (Aug. '43). Recent knowledge of plumbing-borne diseases emphasizes to water works men insufficient to know water safe when leaving pumps or entering bldg. Even more important and difficult to keep it safe until consumer reached. Direct or indirect water poln. by direct or indirect cross-connections large prevention task because of large no. existing. Examples cited. Cross-connections elimd. in city of Bismarck, in state capitol bldg., and at Ft. Lincoln swimming pool. In Jamestown, 2 out of 5 air coolers installed with direct connections from water to sewer. Most dangerous cross-connection type where fire or sprinkling system, using river water, directly connected to city water. Inasmuch as impossible to maint. constantly pressure differential between systems, and closed valve of little protection, pold. water might be pumped into drinking water anytime. Recorded pressure gages in some water systems show remarkable pressure changes by surges from heavy drafts of water at various points. Tall bldgs. and hotels often have undersized water supply piping.—*Ralph E. Noble.*

Water Pollution. Anon. Mil. Surgeon **92**: 335 (Mar. '43). U.S.P.H.S. Dist. office at New Orleans, La., reported diarrheal outbreak, including 1 death and 1 typhoid fever case among dock workers, traced to contamd. water lines by overboard harbor water during fire drill on vessel. General practice to con-

nect ship fire protection lines to wharves water supply lines whenever "steam is down" and ship pumps inoperative. In particular instance, repair work on vessel piping system completed and steam developed to run 5 pumps taking suction from harbor. Pumps operated about 1 hr. creating 100 psi. against 50 psi. city pressure at wharves before realizing city supply connection not broken. Three days later, approx. 200 of 500 dock workers reported ill from diarrhea, with first symptoms in 24 hr. from time contamn. effected. Marked turbidity of water noted and coliform organisms found in 0.1 ml. of samples at wharves. Emergency chlorination used with mobile unit developing 10.0 ppm. residual Cl_2 after thorough flushing. Chlorinated water held in system 48 hr. Officials recommended in future no connection for water supply or fire protection to ships made except through those with double check valve installation. When ships' fire pumps operative, fixed connection to shore protected by double check valves permitted, provided fire pump dischg. valves or other pumps on ship drawing water from outboard sources sealed and provided that latter shall not be removed unless and until fixed shore connection broken.—*Ralph E. Noble.*

A Cross-Connection Jinx. ANON. Am. City **58**: 7: 65 (July '43). Lab. examns. of water samples taken from Entiat, Wash., supply showed periodically bad samples except for entire yr. of '42. Investigation of previous records showed contamd. samples collected after water turned off for repairs. No shutoffs occurred during '42. Further investigation disclosed 3 refrigerator units where cooling water from munic. supply discharged directly to sewer. Sewage may have been drawn into mains during low or negative press. During more thorough survey in surrounding Chelan Co. 32 similar connections found. All subsequently corrected with air-gaps.—*F. J. Maier.*

TREATMENT—GENERAL

Precipitation of Copper From an Acid Mine Water. F. S. WARTMAN & A. H. ROBERSON. Rpt. Invest. U.S. Bur. Min. No. 3476. 16 pp. ('44). At most copper mines copper recovered from waste waters by pptn. with scrap iron. When acid mine water contg. salts of iron and copper brought into contact with metallic iron, copper pptd. and equiv. amt. of iron dissolved, ferric salts reduced to ferrous salts, and sulfuric acid reacts with metallic iron to produce ferrous sulfate. Consumption of iron usually varies from 1 to 1½ lb. of iron per lb. of copper recovered. At Hornet mine of Mountain Copper Co., Calif., consumption of iron 5 to 6 lb. per lb. of copper recovered. Series of tests made with water from Hornet mine and with synthetic mine waters to det. opt. conditions for recovery of copper. In one series of tests in which course of reactions between iron and Hornet mine water followed, effect of increased acidity investigated by adding 5 g. of sulfuric acid to some of samples. Reduction of ferric iron and pptn. of copper proceeded concurrently. Ferric iron and copper reacted with iron more rapidly than did acid. Addn. of acid increased appreciably rate of reduction of ferric iron but had little effect on rate of pptn. of copper. Addn. of acid increased appreciably total consumption of iron. In another series of tests effect of rate of stirring studied. Each of two 1-gal. samples of Hornet mine water kept in contact with piece of iron with area of 245 sq.in.; one sample stirred slowly and other rapidly. Portions of each sample withdrawn at intervals for anal. More rapid stirring increased rate of reduction of ferric iron and of pptn. of copper. In another series of tests effect of concn. of copper studied. Two synthetic mine waters used, one contg. 6.11 g. of copper and 1.0 g. of sulfuric acid per l., and other contg. same concn. of copper and 2.0 g. of sulfuric acid per l. Ratio of copper to total iron in these solns. about 6:7, whereas in natural mine water ratio about 1:20. In synthetic solns. rate of pptn. of copper greater than in mine water but rate relative to rate of reduction of ferric iron less. Another series of expts. made to det. rate at which dil. solns. of sulfuric acid attack metallic iron with and without coating of cement copper. Iron covered with cement copper attacked more quickly than clean iron; during first 8 hr. avg. rates of soln. of iron 0.020 and 0.027 g. per sq. diam. of iron surface per hr. for bare iron and for coated iron respectively. Two tests made to compare consumption of iron

under lab. conditions with consumption at mine. In first test 23 sq.in. of iron surface exposed to 500 ml. of mine water; soln. stirred vigorously for 2¼ hr., when iron in soln. began to hydrolyze. Piece of iron removed, cleaned with wire brush and weighed. Total iron and copper in water detd. Amt. of copper pptd. 0.099 g. or 87.6% of copper present. Total iron in soln. increased by 0.68 g. Piece of metallic iron decreased in weight by 0.72 g. Theoretical amt. of iron required to ppt. 1 g. of copper 4.07 g. In second test thin piece of iron with surface area of 21 sq.in. used to ppt. copper from 5 110-ml. samples of mine water in succession. Total time of exposure of iron 6 hr. 5 min. Each sample of water agitated until iron in soln. began to hydrolyze. Total increase in iron in all solns. 0.692 g.; 110 mg. of copper or about 88.5% of copper present deposited. At end of test piece of iron with copper adhering dissolved in acid and total weight of iron detd. Ratio of iron consumed to copper pptd. based on gain in amt. of iron in soln., 6.3 : 1, and based on loss in weight of piece of iron 8.35 : 1. When excessive consumption of iron due to presence of unusual amts. of ferric iron in mine water, costs cannot be reduced by changing method of pptn. because reduction of iron and pptn. of copper proceed concurrently. Ferric iron could be reduced by filtering water through bed of marcasite but this treatment would be uneconomic with dil. mine water, such as that from Hornet mine. Excessive consumption of iron due to acid can be reduced by controlling period of contact of iron with mine water. Other methods of pptg. copper tested. To 1 l. of mine water, which had pH value of 2.2, added 4 g. of ground marble; after mixt. had been agitated for 10 min. pH value 4.0. Ppt. obtained contained 30% iron; it also contained 10% of copper originally present in mine water. Reduction in amt. of marble added reduced only slightly proportion of total copper present in ppt. Addn. of calcium carbonate to mine water cannot increase pH value much above 4.0 and therefore pptn. of copper incomplete. Freshly slaked lime will ppt. copper from mine water but nearly all iron and alumina pptd. at same time. Treatment of mine water with calcium bisulfite suggested. When soln. of calcium bisulfite added to cold mine water from Hornet mine amt. of calcium sulfate pptd. when mixt. allowed to stand for 20 min. only 50% of theoretical amt. After longer period of standing more calcium sulfate pptd. but ppt. contamd. with copper. When mine water heated almost to boiling point before calcium bisulfite added, about 80% of theoretical amt. of calcium sulfate pptd. in 10 min. and ppt. contained only trace of copper. After filtration to remove calcium sulfate, reasonably complete pptn. of copper could be obtained by boiling filtrate or by agitating filtrate by means of current of steam. Gentle warming of filtrate in vacuum or open to air, or warming, with stream of air passing through filtrate to remove sulfur dioxide, did not ppt. copper. Soln. of calcium bisulfite prepd. by passing sulfur dioxide into suspension of calcium carbonate. Amt. of calcium carbonate required for prepn. of sufficient bisulfite to ppt. copper completely so much greater than theoretical amt. that it seems probable that pptn. due to adsorption rather than to stoichiometric reaction. Tests also made using hydrogen sulfide, calcium monosulfide, calcium polysulfide, ferrous sulfide, and sodium sulfide for pptn. of copper. Hydrogen sulfide, in amt. slightly in excess of theoretical amt., required to ppt. all copper from samples of mine water. One ppt. obtained in this way contained, after drying, 42% copper and at least 15% sulfur soluble in carbon disulfide. Calcium monosulfide in solid form and sodium sulfide in aqueous soln. proved satisfactory but not so good as hydrogen sulfide. Calcium polysulfide ineffective. Freshly pptd. ferrous sulfide satisfactory when used in amts. large enough to reduce ferric iron and to ppt. copper. Ferrous sulfide which had been prepd. dry not satisfactory.—*W.P.R.*

Use of Activated Carbon in Water Treatment. ANON. Wtr. & Wtr. Eng. (Br.) **48**: 469 (Aug. '45). Activated carbon can remove slight tastes and odors, can make dull water bright and sparkling and flat water more agreeable to palate. This is done with min. of attention and low cost. Vessels employed to contain granular activated carbon similar to rapid sand filters but any kind of filter can be used. Grain size of $\frac{1}{16}$" offer little resistance to flow of water. Granular carbon can be used in de-chlorination. It acts as catalyst, accelerating action between chlorine and water to form hydrochloric acid. Quants. are so small that there is little change in pH. Chlor phenols can be removed completely by granular activated carbon. Activated carbon filters should be employed in last phase

of purif. after all other impurities have been removed. Slime can be removed from activated carbon by back-flushing in normal manner. If more drastic action required, 5% soln. of caustic soda may be used for washing, followed by dil. hydrochloric acid. Potassium permanganate can also be used to remove residues from micro-organisms. Full benefit of adsorption properties of activated carbon can be obtained by using activated carbon in powd. form. Normal dosage is from 0.5 to 2 ppm. Recent development is use of activated carbon in blanket form for exclusion of light to inhibit growth of algae in storage reservoirs.—*H. E. Babbitt.*

Better Water Treatment by Proper Sewage Waste Disposal. G. HUDSON STRICKLAND. Eng. Cont. Rec. **58**: 10: 96 (Oct. '45). General discussion of waste disposal in relation to water supply and purif. Difficult to reconcile conflicting interests. Too frequently, reason for tolerating poln. based upon economic considerations. Every waste can be rendered relatively inoffensive at a cost and responsibility for doing so rests upon industry. Expediency rather than design prompted practice of using natural bodies of water for disposal of sewage and it was reasoned that diln. would take care of situation. Several disastrous water-borne epidemics were necessary to show there are limits to natural purif. Not only is water treatment involved, but also recreational use of water bodies, and greater demand for cleanliness of waterways may be anticipated. Not a question of sewage disposal vs. water treatment but of sewage disposal and water treatment, each performing its proper function.—*R. E. Thompson.*

Water Treatment at Koppers Company Plant, Kobuta, Pennsylvania. PAUL J. STEIN. Proc. Ann. Water Conf., Eng. Soc. Western Pa. **5**: 83 ('44). In mfr. of 1 lb. of butadiene, 20 lb. of steam, 35 lb. of treated water, and 1200 lb. of cooling water required. During summer months, 110,000 gal. of Ohio R. water pumped per min. 96% of water untreated, except for intermittent chlorination for slime control. Boiler make-up water clarified and partially softened in Spaulding precipitators (with dolomitic lime, soda ash and copperas), pH adjusted, and final softening obtained with zeolite softeners. Four 350,000-lb./hr. boilers supply 725 lb. steam and require 65% make-up. Uncontamd. water dischgd. directly into Ohio R. Contamd. water detained 2.5 hr. to allow insoluble oils to separate, treated with lime to neutralize acidity and dischgd. Sanitary sewage treated in Imhoff tanks.—*C.A.*

Recent Experiences in Demineralizing Water. M. E. GILWOOD & V. J. CALISE. Proc. Ann. Water Conf., Eng. Soc. Western Pa. **5**: 11 ('44). Demineralizing units designed for flow rates of 4, 55, and 1000 gpm. of treated water described. Operating cost of demineralization ranges from 1¢ to 20¢ per 1000 gals. depending on type of water treated, compared to 80¢ to $8.00 per 1000 gals. for com. distd. water. With water high in SO_4^{--} and Cl^-, recycling effluent of H exchanger decreased mineral content of finished water.—*C.A.*

TNT Wastes From Shell-Loading Plants. Color Reactions and Disposal Procedures. C. C. RUCHHOFT, M. LEBOSQUET JR. & WILLIAM G. MECKLER. Ind. Eng. Chem. **37**: 937 ('45). Study of problem of disposal of liquid wastes from TNT bomb- and shell-loading plants including factors affecting conversion of TNT in these waters to colored deriv. Natural degradation of TNT too slow for application to treatment of wastes. Small quants. of either TNT or its colored deriv. reduce rate of biochem. oxidation in pold. waters without reduction of TNT. Activated-sludge treatment ineffective. Soil absorption and activated-charcoal treatment found to be most promising procedures for removal of TNT from waste waters.—*C.A.*

Electrochemical Purification of Water From O. A. I. KRASIL'SHCHIKOV & L. M. VOLCHKOVA. J. Applied Chem. (U.S.S.R.) **17**: 242 ('44). (English summary.) Electrochem. removal of O from water at Fe electrodes based on cathodic reduction of O plus simultaneous absorption of O by $Fe(OH)_2$ (formed in electrolysis). Process leads to complete O removal from water. Cost less at increased temp. and decreased rate of flow of water in cell; at space rate of 15–20 l./hr. at 70–80° there are used 0.05–0.06 kwhr. and 30–40 g. Fe per cu.m. of water.—*C.A.*

Potable Sea Water. ANON. Engineering (Br.) **160**: 395 (Nov. 16 '45). Acct. of methods of prepg. water fit for drinking from sea water by base-exchange process has been issued by Royal Naval Scientific Service through Ministry of Information. Early

work concerned with developing some form of still. In Visscher still heat of body utilized to evap. water in small boiler, under manually induced vacuum, vapor being condensed in coil immersed in sea. In Ambrust cup method moisture in breath condensed in wet felt-jacketed container. Delano solar still utilizes solar radiation, while it has greater output than other two, its eff. depended on amt. of sunshine and was relatively fragile. In July '41, Director of Scientific Research approached Messrs. Permutit Co., Ltd., to co-operate in investigating base-exchange materials in treatment of sea water. Mixed barium-silver zeolite evolved. This mixed zeolite can be used for removal simultaneously of chlorides and sulfates in proportions found in sea water. General principle of obtaining clear drinking water from sea water is to place charge of sea water and zeolite briquettes in flexible bag having lining of filter cloth. Water and briquettes shaken up and bag squeezed to drive treated water through filter cloth into receptacle, all suspended ppts. and zeolites being retained in bag. App. as finally agreed upon consists of flexible purifier made of rubberized fabric, 9 chem. charges contained in rubberized fabric storage bag, and Perspex drinking receptacle in which rest of equip. packed.—*H. E. Babbitt.*

Drinking Water From Sea Water by a Chemical Method. E. I. AKEROYD, E. L. HOLMES & A. KLEIN. Wtr. & Wtr. Eng. (Br.) **48**: 556 (Oct. '45). Practical chem. method has been developed based on properties of ion-exchange materials. Ion-exchange material made having exchangeable silver (silver zeolite). This reacts with NaCl solns. in following manner:

$NaCl$	+	Ag_2Z	=	Na_2Z	+ $2AgCl$
In solution		Insoluble solid		Insoluble solid	Insoluble solid

Percolating technic of passing water through column of silver zeolite found impracticable owing to formation of silver chloride ppt. Shaking technic adopted; chloride soln. and powd. silver zeolite being shaken to keep all reagents and products of reaction in suspension. Similar expts. on sodium sulfate solns. were carried out using ion-exchange material contg. barium zeolite. It was found that mixt. of silver zeolite and barium zeolite would remove dissolved chlorides and sulfates from sea water after shaking for ½ hr. Removal of greater part of magnesium ions another problem that had to be solved. It was found that excellent magnesium removal could be obtained if mixed barium-silver zeolite were made by passing soln. of barium hydroxide through silver zeolite. Mixed zeolite produced contained proportion of silver oxide. This was pptd. in situ in finely divided condition. More effective in removal of magnesium than artificial mixt. of silver oxide with either mixed or separate zeolites. In constr. of app., chems. compressed into briquettes which became rock hard. Disrupting agent to break up briquettes when they came into contact with water was activated fuller's earth. Final reagent consists of mixed barium-silver zeolite contg. quant. of pptd. silver oxide together with disrupter. In addn., small amt. of activated carbon to produce bright, clear drinking water. To facilitate briquetting process small amt. of graphite added. Best method of obtaining clear drinking water is to treat sea water and briquettes in flexible bag of rubberized fabric fitted with filter cloth. After shaking water and reagents, drinking water can be filtered by squeezing bag so that water passes through filter cloth. App. includes 9 chem. charges, each of which will produce ½ pt. of water. Over-all size is $3'' \times 3'' \times 4\frac{3}{8}''$. Amt. of water provided by app. is six times as much as that which could be carried in tin occupying same space in airman's pack.—*H. E. Babbitt.*

Present Status of Fluorination of Municipal Water Supplies. A. E. BERRY. Wtr. & Sew. **83**: 3: 21 (Mar. '45). When drinking water contains excessive F, mottled enamel prevalent, but with concn. of about 1 ppm. dental caries less than when water contains little or no F. Latter indicates F is essential factor in tooth decay but does not exclude possible effects of other constituents. To obtain more direct information, addn. of F to water supply being undertaken at Brantford, Ont., Newburgh, N.Y., and Grand Rapids, Mich. Treatment commenced at latter Jan. 25, '45, and will be started soon in other two. All 3 have gravity mech. filter plants and at each NaF of 90–95% purity will be applied with dry feed equip. At Newburgh and Brantford, white powd. will be colored Nile blue to distinguish it from other chems. Although application to filtered water considered best to avoid loss, point of application at Grand Rapids and Brantford will be immediately ahead of filters to facilitate adjustment of dosage. Tests at former

showed no appreciable loss when applied after coagulation and settlement but that loss occurred if added prior to coagulation. Cost at Brantford, with consumption of 4 mgd., estd. at $3300 per yr. to increase F from something less than 0.2 ppm. to 1 ppm. Surveys of F content of Ontario supplies being made and dental studies contemplated at some places. Until more data available, not suggested that fluorination be adopted on wide scale.—*R. E. Thompson.*

Purification of Water. HUBERT L. OLIN. U.S. 2,362,022 (Nov. 7, '44). Water purified in 2-stage process with aid of Na bentonite, suspended in portion of water, making approx. 5% suspension. This suspension added to major part of water using 15–125 ppm. of Na bentonite. If treated water does not contain enough bivalent cations to flocculate bentonite, they should be added as, e.g., CaO either before or after addn. of bentonite. Water agitated to promote flocculation and then left to settle out. Supernatant liquid drawn off and treated with 5–15 ppm. of a trivalent (Al or Fe) metal. After thorough mixing, water filtered or allowed to settle out and purified H_2O separated by filtration. —*C.A.*

Water Treatment Saves Large Sums. T. W. HISLOP. Ry. Age **118**: 5: 270 (Feb. 3, '45). Detailed survey made by New York Central RR. in '24 demonstrated that cost of locomotive boiler maint. and fuel consumption varied directly with qual. of water used. This resulted in installation of treating facilities at 253 water stations, employing 34 lime-soda softeners, 78 liquid proportioners and 141 bypass feeders. Present check indicates annual net saving of over $2,500,000. Success of locomotive water treatment program depends on uninterrupted addn. of proper chem. treatment and following of predetermined blow-down schedule.—*R. C. Bardwell.*

Use of Activated SiO_2 in the Coagulation of Highly Colored Water. R. E. NOREUS. Paper Trade J. **120**: 11: 45 ('45). When Na silicate treated with various chems. to release most of SiO_2 from alkali, aged for some time, and then dild. at some point before micelles have become large enough to form a gel, activated SiO_2 formed which has been found to improve coagulation of water greatly. Use of this material in treatment of highly colored soft water has resulted in lower settled effluent turbidities, lower filtered water colors and increased filter runs. These improvements attributed to much lower effluent turbidities resulting from heavier, faster-settling coagulation.—*C.A.*

The Purification of Emergency Water Supplies. *Report by the British Water Works Association Technical Advisory Committee on the Pollution, Purification and Treatment of Water Supplies.* Off. Cir. Br. W.W. Assn. **24**: 233 ('42). To simplify application of methods for purifying emergency water supplies, sources of such supplies divided into 2 classes. Class I comprises all surface waters and certain pold. underground waters which may contain suspended matter and require clarification. Class II includes underground waters which might or might not be bacterially pold., but which do not contain visible suspended matter. Disinfection only treatment required for such waters. Where use of heavily pold. water would be necessary in emergency, recommended that suitable methods of treatment be ascertained in advance as std. methods of treatment not suitable. Filtration recommended for clarifying waters of Class I, but when filtration plant not available, water should be treated by addn. of alumino-ferric and settling. Details of processes recommended given in Part II of report. Dose of 5 g. alumino-ferric per gal. recommended for coagulation in most waters. If waters acidic, addn. of finely powd. or pptd. chalk necessary before alumino-ferric added. For disinfection 120 g. of "Stabochlor" (stabilized bleaching powd. contg. 34–36% available Cl) made into thin cream and added to 100 gal. clarified water. After stirring and allowing to stand for 15 min., test for residual chlorine made by adding cadmium or potassium iodide and starch soln. to sample of water. If blue-black color does not develop, chlorination should be repeated. If residual chlorine detected, water may be de-chlorinated before use by addn. of 3 fluid oz. soln. contg. 1 lb. sodium thiosulfate per gal.—*W.P.R.*

Small Schemes for Water Purification. P. J. MCCARTHY. (*A paper presented before Inst. of Civ. Engrs. of Ireland.*) Civ. Eng. (Br.) **38**: 224 (Oct. '43). Water purif. comparatively new science, having been studied since about 1860. Mech. filtration developed in U.S. Difficulty of obtaining information from text books easily understood since type

of plant usually described some single plant in England or abroad which daily filters enough water to supply whole of Ireland. Following suggestions deal with schemes providing 200,000 gpd. (Imp.) Impurities in water, usually removed by filtration, in suspension and soln. For dissolved impurities, such as lime and magnesia, chem. agents employed. Natural filtration means utilizing well-known purifying properties of earth to remove impurities from water. Natural purif. of high std. and ideal solution under favorable circumstances. Usefulness of slow sand filters limited and with advent of mech. filter, fallen out of favor. Qual. of crude water and rate of filtration have definite bearing on qual. and size of sand used. Sand which will pass $\frac{3}{16}''$ ring with about 80% larger particles, satisfactory in slow sand filter. Sand should be renewed when depth reduced to about 12" thickness of bed. Adoption of slow sand filters confined to waters not heavily pold. Important accessory to most filter schemes is settling tank. Uneconomical to provide filters to do work that can be done in plain tank by sedimentation. *Ibid.* **38:** 251 (Nov. '43). *Application of Chemicals to Crude Water.* Chems. added previous to filtration known as coagulants. Alum commonest chem. used. Sulfuric acid, occasionally recommended for lowering pH, not safe liquid to use except under expert supervision. On small schemes usual method of controlling dosage is to mix soln. of known strength and inject it into water at fixed rate. Type of treatment employed for water of high temporary hardness, heavy poln. and high bact. content, commonly called "excess lime process," which combines softening and sterilizing. Probable that on small schemes gravity filter more satisfactory than pressure type.—*H. E. Babbitt.*

Problems of Water Hygiene. K. SCHLIRF. Öff. Gesundh-Dienst (Ger.) **7:** 2: 41 ('41); Gesundheits Ing. (Ger.) **64:** 600 ('41). Discusses various regulations adopted at different times with regard to san. condition of water supplies in Germany. Conditions of water supply on north German plains difficult. In region of river Weser, streams often have high content of salt owing to discharge of potash waste waters. Salinity, presence of high content of iron, often combined with humic acids difficult to ppt., occurrence of peaty water and presence of aggressive carbon dioxide comprise main problems of dist. Small quants. of water disinfected by boiling or filtering. On large scale, disinfection usually by filtration and chlorination. Water contg. more than 100 bacteria per ml. should be chlorinated. Chem. examn. shows that water used for supply in northwest Germany frequently contains as much as 20–40 mg./l. iron; this condition promotes growth of iron bacteria in water systems. Drinking water supplies should not contain more than 0.1 mg./l. iron. Cases of lead poisoning caused by water supply occur sporadically in Oldenburg region, where large amts. of salt present; even in ground water of Weser region contents of 200 to 300 mg./l. produced by discharge of potash waste waters. Worse conditions prevail in Oldenburg-Friesian dist. Thus, water of poor qual. often supplied for drinking purposes. Ground waters of North Sea Islands less saline, as rain water which has filtered through sand dunes forms upper layer over the salt water.—*W.P.R.*